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By B. B. RAE, M.A., B.Sc., Ph.D.

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CONTENTS

	Page
Introduction	3
Collection of Material	3
Identification of Developmental Stages	4
General Discussion of the Records by Months	10
Spawning Period	22
Spawning Places	24
Dispersal of Eggs and Larvæ	25
Vertical Distribution of the Larvæ	26
Brood Fluctuations	28
Average Sizes of the Larvæ	29
Distribution of the Most Advanced Larvæ in Relation to the Occurrence of the Younger Bottom Stages	31
Summary	34
References	35

The Occurrence of Lemon Sole Larvæ in the Scottish Plankton Collections of 1929, 1930 and 1931

INTRODUCTION

The development of the egg and larva of the lemon sole has been described by McIntosh (1890), terman (1892), Kyle (1897) and Ehrenbaum (1909). More recent investigations have clarified e aspects of the biology of adolescent and adult lemon soles but gaps in our knowledge of this species remain to be filled and it was with this aim that an examination of the larvæ in the plankton catches ıe Scottish research vessel for the years 1929, 1930 and 1931 was undertaken. These three years, esenting one year (1930) of very good brood survival and two of poor survival in Scottish waters, etermined in later years from an age analysis of trawl catches, were selected in order to see whether relationship existed between the numbers of larvæ in the plankton and the subsequent adult brood ıgths. A preliminary paper (Rae 1938) has already given some of the results of the examination .e 1931 larvæ. These have been incorporated in the present account.

COLLECTION OF MATERIAL

Three different nets were used in the collection of the material during the years under review.

1. *The two-metre ring with a net of cheese-cloth,* which was employed for taking vertical hauls from near ottom to the surface. This net was generally used with success but the operation was discontinued period in 1929, and, consequently, the records for this year are the poorer as a result of this omission.

2. *The one-metre ring net, also of cheese-cloth,* which was used for making horizontal hauls of 15 minutes' tion at the surface, in midwater and near the bottom to a maximum depth of 100 metres.

3. *The Agassiz stramin net on a rectangular frame,* which was employed for taking horizontal hauls of an hour's duration (comprising 10 minutes at the surface, in mid-water and at the bottom). This was used at depths of over 100 metres as well as in more shallow waters. An advantage of the siz stramin net over the one-metre townets is that it can be towed closer to the sea bottom without ring the danger of damage to the net.

In general, during the years 1929 to 1931, the working of a full plankton station involved the use three nets described above, thus giving five separate collections. As explained already, however, wo-metre net was withdrawn from use for a time in 1929 and throughout the period the Agassiz in was also omitted on occasion owing to the difficulty in working the gear in bad weather or to lose proximity of certain stations, in which case it was employed at alternate stations. The three netre townets were, however, used at practically all stations unless in very shallow water, when the ater net was omitted. Some indication of the extent of the records derived from these nets and of eneral location of the larvæ, as regards the depths at which they are found, is obtained from Table ng the totals of the larvæ taken during each year, together with the number of hauls from the begin- of April (the first month in which larvæ were caught) to the end of November (the last month in ı larvæ were taken).

TABLE 1

Means of Capture of Lemon Sole Larvæ

Year	Type of Net	Youngest Stages 1, 1/2, 2	Intermediate Stages 2/3, 3, 3/4, 4, 4/5, 5	Oldest Stages 5/6, 6	Totals	No. of Hauls April-Nov. inc.	No. Posit Hau
1929	2m. ch. cl.*	2	4	1	7	68	5
	1m ch. cl. surface ..	3	4	1	8	202	7
	1m. ch. cl. mid-water ..	90	74	10	174	197	30
	1m. ch. cl. bottom to 100m.	100	196	6	302	202	45
	Agassiz stramin	6	57	8	71	106	18
	All Nets	201	335	26	562	775	105
1930	2m. ch. cl.	98	85	5	188	242	60
	1m. ch. cl. surface ..	4	5	6	15	249	9
	1m. ch. cl. mid-water ..	107	42	5	154	239	42
	1m. ch. cl. bottom to 100m.	106	159	33	298	249	75
	Agassiz stramin	190	550	87	827	233	75
	All Nets	505	842	135	1,482	1,212	261
1931	2m. ch. cl.	264	173	15	452	200	6
	1m. ch. cl. surface ..	11	12	6	29	198	9
	1m. ch. cl. mid-water ..	105	77	3	185	171	3
	1m. ch. cl. bottom to 100m.	275	252	13	540	198	5
	Agassiz stramin	77	253	59	389	151	4
	All Nets	732	767	96	1,595	918	20

* m. ch. cl.=metre cheese cloth.

The collections were preserved in weak formalin and the separation and identification of the l were carried out in the laboratory as circumstances permitted during the succeeding years.

IDENTIFICATION OF DEVELOPMENTAL STAGES

In the identification of the larvæ and of the various stages from the newly-hatched indivi to the most advanced post-larval stages papers by McIntosh (1890), Petersen (1904) and Ehren (1909) have been consulted and for the purposes of the present report the following stages have defined:—

STAGE 1: This includes all larvæ from hatching up to the complete absorption of the yol and is characterised by the presence of a pronounced depression in front of the anus similar to illustrated by Ehrenbaum (1909, fig. "d") and by McIntosh (1890, fig. 4, plate XI).

STAGE 2: This stage in which the depression in front of the anus has disappeared, show expansion of the marginal embryonic fins. The caudal fin appears in the form of a transl portion on the embryonic fin near the ventral half of the first pigment spot, *vide* Petersen (1 fig. 16).

STAGE 3: The body is deeper and the embryonic fin broader. Fin rays are now visible in the caudal fin though there is no indication of the notochord bending upwards. The "a" and "b" pigment spots are now represented in the dorsal region, *vide* Petersen (1904, fig. 17).

STAGE 4: The notochord is definitely heterocercal and the caudal fin much developed. The body is deeper and traces of fin-ray supports are visible at the base of the embryonic fin. The left eye is beginning to migrate, *vide* Petersen (1904, fig. 18).

STAGE 5: The heterocercal condition of the notochord is more advanced. Fin-ray supports are well developed and the fin rays of the dorsal and ventral fins extend about half-way to the margin of the embryonic fins. The eye is showing above the head, *vide* Petersen (1904, fig. 19).

STAGE 6: No trace remains of the embryonic fins. The dorsal and ventral fins are separated from the caudal fin. The pectoral and pelvic fin rays are now rapidly developing. The body is deeper and the pigmentation more marked. The eye is advancing over the ridge. In this group all the more advanced larvæ have also been included in order to avoid the creation of additional stages in which the numbers of individuals would be small.

Little attempt has been made in the works consulted to estimate the age of the larvæ at the various ;s. Ehrenbaum gave the age of stage 1 as 8 days and McIntosh stated that the yolk is almost com-·ly absorbed after 4 days. Stage 1 therefore includes larvæ from those newly-hatched up to those ys old. Surprisingly few larvæ with the yolk-sac intact or even with part of the yolk still to be absorbed identified in the collections and the majority of the individuals in stage 1 answered fairly closely e description given above. This became more noticeable as the season advanced and it may be that ıbsorption of the yolk and general development is accelerated as the sea temperature rises to its in the latter half of the year.

In an attempt to ascertain the approximate age at which larvæ enter stage 6 of the developmental s, the first records of this stage in each of the three years under examination have been correlated the beginning of spawning in the particular region in which they were found. Thus two larvæ ıge 6, caught north of the Butt of Lewis in the last days of May, are estimated to have resulted from ning in the latter half of March and several individuals at the same stage of development caught e Moray Firth in mid-July must have resulted from spawning in the first half of May. In each case ·vidence leads to the view that stage 6 is reached in almost two months from the time of hatching ›ugh it is possible that development may be speeded up or retarded according to whether conditions avourable or unfavourable and that no hard and fast statement can be made on the subject.

During the examination of the material it often proved difficult to decide to which stage larvæ ıged and accordingly intermediate stages have also been recognised.

As the publication of the complete lists of stations and results would occupy considerable space, s been found necessary to condense the tables by the combination of stations in convenient regions. results of the investigations are set forth in tables 2, 3 and 4.

As may be expected, the operation of a single research vessel in such a wide area as that covered ıe *Explorer* inevitably results in blank spaces in the arrangement of the data from month to month from place to place, but it is considered that, notwithstanding the imperfections, some reliable usions can be drawn.

TABLE 2

Lemon Sole Larvæ, 1929

Date	Locality	No. of Hauls: All Nets	No. of Larvæ	Developmental Stages									
				1	1/2	2	2/3	3	3/4	4	4/5	5	5
3 May	East of Moray Firth	6	0	—	—	—	—	—	—	—	—	—	
4–6 „	Moray Firth	16	0	—	—	—	—	—	—	—	—	—	
6–17 „	Fair Isle to W. Shetland	15	1	—	—	1	—	—	—	—	—	—	
18–28 „	Faroe-Faroe Bank	28	0	—	—	—	—	—	—	—	—	—	
28–29 „	N. of Butt of Lewis and N. end of Minch	20	28	—	2	12	7	5	2	—	—	—	
		85	29	—	2	13	7	5	2	—	—	—	
2 June	West of Orkneys	10	85	5	10	18	11	18	16	6	—	1	
5 „	Outer Moray Firth (C15)	4	11	4	3	2	1	—	—	1	—	—	
5–18 „	Aberdeenshire Coast	14	5	—	—	1	1	3	—	—	—	—	
18–19 „	East of Moray Firth and Northwards	20	13	—	—	2	2	5	3	—	1	—	
20–22 „	North Shetland	14	24	—	—	4	4	7	3	2	—	1	
23–27 „	North East Faroes	11	0	—	—	—	—	—	—	—	—	—	
29–30 „	E. of Flugga to Viking Bank	21	0	—	—	—	—	—	—	—	—	—	
		94	138	9	13	27	19	33	22	9	1	2	
1–5 July	East of Shetlands	14	3	—	2	1	—	—	—	—	—	—	
15 „	Fair Isle	10	16	—	11	1	—	1	1	1	—	1	
15–16 „	Bressay Shoal and East of Orkneys	20	13	—	1	7	—	3	1	1	—	—	
17 „	Moray Firth	11	167	—	14	42	10	40	23	17	14	3	
18–19 „	Outer Moray Firth	13	84	—	6	36	11	11	8	6	4	1	
30 „	Aberdeenshire Coast—(Turbot Bank)	3	5	—	—	—	—	—	—	2	3	—	
		71	288	—	34	87	21	55	33	27	21	5	
6–27 Aug.	The Minch	44	1	—	—	—	—	—	—	—	—	—	
13–17 „	Firth of Clyde	60	0	—	—	—	—	—	—	—	—	—	
17 „	North of Ireland	4	0	—	—	—	—	—	—	—	—	—	
27–29 „	Butt of Lewis to Orkneys	35	10	—	—	—	—	4	5	1	—	—	
30 „	Moray Firth	10	11	—	—	—	—	4	4	2	1	—	
		153	22	—	—	—	—	8	9	3	1	—	
5–20 Sept.	Firth of Forth	24	12	—	—	—	2	2	2	2	—	1	
10–25 „	Aberdeenshire Coast	20	51	—	3	10	3	2	6	10	7	4	
11–17 „	Central North Sea	68	8	—	—	2	1	—	1	2	—	1	
		112	71	—	3	12	6	4	9	14	7	6	
8–10 Oct.	Moray Firth and East of Orkney	25	6	—	—	—	—	—	—	—	2	1	
15–27 „	Shetlands	54	3	—	—	—	—	—	—	—	—	—	
28–29 „	Outer Moray Firth, etc.	20	0	—	—	—	—	—	—	—	—	—	
		99	9	—	—	—	—	—	—	—	2	1	
14–15 Nov.	Off Berwickshire and N.E. English Coasts	20	5	—	1	—	—	1	—	1	1	—	
15–20 „	Firth of Forth	40	0	—	—	—	—	—	—	—	—	—	
21–27 „	Off Aberdeenshire and Kincardineshire Coasts	23	0	—	—	—	—	—	—	—	—	—	
		83	5	—	1	—	—	1	—	1	1	—	

TABLE 3

Lemon Sole Larvæ, 1930

te	Locality	No. of Hauls: All Nets	No. of Larvæ	Developmental Stages										
				1	1/2	2	2/3	3	3/4	4	4/5	5	5/6	6
April	Aberdeenshire Coast	5	0	—	—	—	—	—	—	—	—	—	—	—
,,	Moray Firth	15	0	—	—	—	—	—	—	—	—	—	—	—
,,	E. Orkney, Fair Isle, Scalloway Deep	24	0	—	—	—	—	—	—	—	—	—	—	—
,,	West of Orkneys	15	2	2	—	—	—	—	—	—	—	—	—	—
,,	Minch	17	16	14	2	—	—	—	—	—	—	—	—	—
,,	Skerryvore to Irish Coast	9	0	—	—	—	—	—	—	—	—	—	—	—
,,	Firth of Clyde	109	0	—	—	—	—	—	—	—	—	—	—	—
,,	Islay to S.W. of Barra Head	13	46	22	24	—	—	—	—	—	—	—	—	—
,,	Moonen Bay, Skye	4	10	5	5	—	—	—	—	—	—	—	—	—
,,	Butt of Lewis to Orkneys	15	39	22	13	4	—	—	—	—	—	—	—	—
,,	Moray Firth	10	0	—	—	—	—	—	—	—	—	—	—	—
,,	Aberdeenshire Coast	10	0	—	—	—	—	—	—	—	—	—	—	—
		246	113	65	44	4	—	—	—	—	—	—	—	—
May	St. Andrews Bay	5	0	—	—	—	—	—	—	—	—	—	—	—
,,	Aberdeenshire Coast	5	0	—	—	—	—	—	—	—	—	—	—	—
,,	Moray Firth	25	0	—	—	—	—	—	—	—	—	—	—	—
,,	N. North Sea including Fladen Ground and Viking Bank	78	0	—	—	—	—	—	—	—	—	—	—	—
,,	Shetlands (Flugga to Balta)	20	9	—	—	1	—	3	3	—	—	1	1	—
		133	9	—	—	1	—	3	3	—	—	1	1	—
une	Fair Isle	15	19	—	3	6	3	5	2	—	—	—	—	—
,,	E. of Orkneys including North Sound	15	16	—	2	5	3	3	3	—	—	—	—	—
,,	Moray Firth	19	44	—	8	29	4	2	—	1	—	—	—	—
,,	Aberdeenshire Coast	9	11	—	1	8	2	—	—	—	—	—	—	—
,,	Central N. Sea including Fisher Bank	65	9	—	—	4	3	2	—	—	—	—	—	—
,,	Firth of Forth including St. Andrews Bay	13	0	—	—	—	—	—	—	—	—	—	—	—
,,	Entrance to Dornoch and Cromarty Firths	8	0	—	—	—	—	—	—	—	—	—	—	—
,,	Aberdeenshire Coast	8	6	—	3	3	—	—	—	—	—	—	—	—
		152	105	—	17	55	15	12	5	1	—	—	—	—
uly	E. of Aberdeenshire Coast including Fladen Ground	30	22	—	3	—	3	9	1	—	1	2	2	1
,,	Outer Moray Firth	5	14	—	2	3	1	4	2	2	—	—	—	—
,,	East of Orkneys	5	10	—	1	4	1	2	1	—	—	1	—	—
,,	Northern N. Sea (Cent.)	30	8	—	1	1	2	1	—	1	1	—	1	—
,,	Shetlands	13	26	—	3	2	5	9	2	—	—	2	1	2
,,	Fair Isle	20	46	—	5	6	7	7	6	6	2	5	—	2
,,	Moray Firth	25	310	1	79	80	22	48	32	25	11	7	4	1
,,	Aberdeenshire Coast	5	4	—	1	—	—	—	—	2	1	—	—	—
		133	440	1	95	96	41	80	44	36	16	17	8	6

TABLE 3—(*continued*)

Lemon Sole Larvæ, 1930

Date	Locality	No. of Hauls: All Nets	No. of Larvæ	Developmental Stages									
				1	1/2	2	2/3	3	3/4	4	4/5	5	5/6
5 August	E. of Moray Firth	14	28	—	4	7	1	4	6	2	3	—	—
6 „	Outer Moray Firth	5	11	—	8	3	—	—	—	—	—	—	—
8–9 „	West of Orkneys	9	14	—	—	—	1	2	—	2	1	2	—
9–11 „	The Minch	28	12	—	—	3	2	1	—	2	2	—	
13–24 „	Firth of Clyde	34	1	—	—	1	—	—	—	—	—	—	—
24–25 „	N. of Irish Coast	10	1	—	—	—	—	—	—	—	—	—	—
25 „	S.W. of Barra Head	5	25	—	—	—	—	—	—	—	—	—	—
26–27 „	Southern Minch	10	0	—	—	—	—	—	—	—	—	—	—
27–29 „	St. Kilda—Flannan Isles	31	22	—	—	—	—	—	—	—	—	—	—
29 „	N. of Butt of Lewis	5	0	—	—	—	—	—	—	—	—	—	—
		151	114	—	12	14	4	7	6	6	6	2	
1–3 Sept.	Northern Minch	20	2	—	—	—	—	—	1	—	1	—	—
3–5 „	West of Orkneys	25	11	—	—	—	1	4	1	4	—	1	—
5–12 „	Moray Firth and Eastward	42	88	—	7	10	11	9	11	15	9	7	
10–16 „	Aberdeenshire Coast	46	402	—	17	36	24	63	87	74	37	33	1
17–30 „	South East of Aberdeen (C12: C11)	15	52	—	2	7	7	13	10	8	1	2	—
17–27 „	Firth of Forth	43	50	—	1	5	9	10	9	10	3	—	
30 „	Cove Bay (Kincardine); Lunan Bay (Angus)	10	2	—	—	—	1	1	—	—	—	—	—
		201	607	—	27	58	53	100	119	111	51	43	1
2–12 Oct.	Central N. Sea (Western half) ..	48	83	—	4	12	13	11	8	15	4	5	
28–29 „	Aberdeenshire Coast (including Aberdeen Bay)	14	0	—	—	—	—	—	—	—	—	—	—
		62	83	—	4	12	13	11	8	15	4	5	
1–2 Nov.	Outer Moray Firth	30	3	—	—	—	—	—	—	—	—	1	
2–19 „	Moray Firth	29	5	—	—	—	—	—	—	—	—	—	—
6–18 „	Fair Isle to S. Shetland	25	0	—	—	—	—	—	—	—	—	—	—
25–26 „	Aberdeenshire Coast	10	2	—	—	—	—	—	—	—	—	—	
26–27 „	Central North Sea (Western half) ..	25	1	—	—	—	—	—	—	—	1	—	—
28 „	South-East of Aberdeen (C12: C11)	10	0	—	—	—	—	—	—	—	—	—	—
		129	11	—	—	—	—	—	—	—	1	1	

TABLE 4

Lemon Sole Larvæ, 1931

Date	Locality	No. of Hauls All Nets	No. of Larvæ	Developmental Stages										
				1	1/2	2	2/3	3	3/4	4	4/5	5	5/6	6
May	Moray Firth	13	0	—	—	—	—	—	—	—	—	—	—	—
,,	E. Orkney—Fair Isle	15	30	2	16	10	1	1	—	—	—	—	—	—
,,	West Shetlands	13	7	—	3	2	1	1	—	—	—	—	—	—
,,	Faroe—Faroe Bank	40	3	2	—	1	—	—	—	—	—	—	—	—
,,	Butt of Lewis—Sulisker	9	85	2	7	15	4	31	9	6	8	1	—	2
		90	125	6	26	28	6	33	9	6	8	1	—	2
June	Northern Minch—Broad Bay	2	3	—	—	—	—	2	1	—	—	—	—	—
,,	West of Orkneys	13	143	25	25	20	10	17	16	19	9	2	—	—
,,	S.W. Shetlands	9	176	7	60	53	22	22	6	4	1	1	—	—
,,	N.W. Shetlands	10	105	27	21	26	10	10	6	3	—	2	—	—
,,	East Shetlands	17	36	1	3	9	4	10	3	2	3	1	—	—
,,	Moray Firth (Outer)	9	86	5	20	22	10	10	9	4	3	3	—	—
,,	Aberdeenshire Coast	11	64	2	8	11	8	8	7	5	8	4	2	1
,,	Northern N. Sea (Central Section)	40	11	1	5	3	1	—	—	1	—	—	—	—
,,	Fair Isle	5	32	7	7	10	4	2	1	1	—	—	—	—
		116	656	75	149	154	69	81	49	39	24	13	2	1
July	Northern North Sea—(Central Section)	25	19	—	3	5	—	3	3	—	1	3	—	1
,,	East Shetlands	2	8	1	5	2	—	—	—	—	—	—	—	—
,,	Fair Isle	17	43	4	12	15	2	4	2	1	1	2	—	—
,,	Moray Firth (B15a)	5	128	—	10	28	17	34	14	13	—	5	4	3
,,	Outer Moray Firth	11	222	1	44	46	32	51	20	16	4	2	2	4
,,	Aberdeenshire Coast	15	59	1	5	21	14	8	4	4	—	—	2	—
,,	Firth of Forth	28	0	—	—	—	—	—	—	—	—	—	—	—
		103	479	7	79	117	65	100	43	34	6	12	8	8
Aug.	Aberdeenshire Coast	29	39	1	6	8	4	5	3	3	2	2	1	4
,,	Central North Sea	35	23	—	4	9	3	3	—	2	—	—	1	1
,,	Central North Sea	26	7	—	—	—	—	2	1	—	2	2	—	—
,,	Moray Firth	21	81	2	7	23	12	17	3	7	3	3	1	3
,,	Fair Isle	16	14	—	—	—	—	—	2	—	3	—	5	4
,,	Northern North Sea	14	5	—	—	1	—	1	1	—	—	—	—	2
,,	Aberdeen and St. Andrews Bays	6	0	—	—	—	—	—	—	—	—	—	—	—
		147	169	3	17	41	19	28	10	12	10	7	8	14
Sept.	Firth of Forth	21	0	—	—	—	—	—	—	—	—	—	—	—
,,	Central North Sea	45	52	—	3	11	2	2	6	10	7	5	3	3
,,	Aberdeenshire Coast	20	33	—	3	2	—	2	1	8	3	8	2	4
,,	Outer Moray Firth	10	3	—	—	—	1	—	1	1	—	—	—	—
,,	Moray Firth	21	30	—	—	1	—	1	—	1	1	1	2	23
,,	West of Orkneys	20	10	—	—	—	1	1	—	1	—	1	2	4
,,	E. of Orkneys and Fair Isle	10	1	—	—	—	—	—	—	—	—	—	—	1
,,	West of Shetlands	20	5	—	1	1	—	—	—	—	1	—	—	2
,,	East of Shetlands	10	0	—	—	—	—	—	—	—	—	—	—	—
		177	134	—	7	15	4	6	8	21	12	15	9	37
Oct.	Northern North Sea	10	1	—	—	—	—	—	—	—	—	—	—	1
,,	East of Moray Firth	5	2	—	—	—	—	—	—	—	—	—	1	1
,,	St. Andrews Bay	4	0	—	—	—	—	—	—	—	—	—	—	—
		19	3	—	—	—	—	—	—	—	—	—	1	2
Nov.	Firth of Forth (Outer)	5	9	—	—	1	1	1	—	2	2	1	1	—
,,	Central North Sea—(Western Section)	56	20	—	1	6	3	3	2	2	—	—	2	1
,,	Aberdeenshire Coast	5	0	—	—	—	—	—	—	—	—	—	—	—
		66	29	—	1	7	4	4	2	4	2	1	3	1

GENERAL DISCUSSION OF THE RECORDS BY MONT

February/March: Although widespread operations were conducted during the months of Feb and March in the North Sea and adjacent waters off the north and north-west coasts, including the re most densely populated by adult lemon soles, no larvæ were taken in the plankton catches. This state has been made because there is on record at least one instance of a post-larval lemon sole being c in a bottom tow-net off the Firth of Forth in February, 1907, but there seems to be no doubt tha specimen belonged to the brood of the previous year.

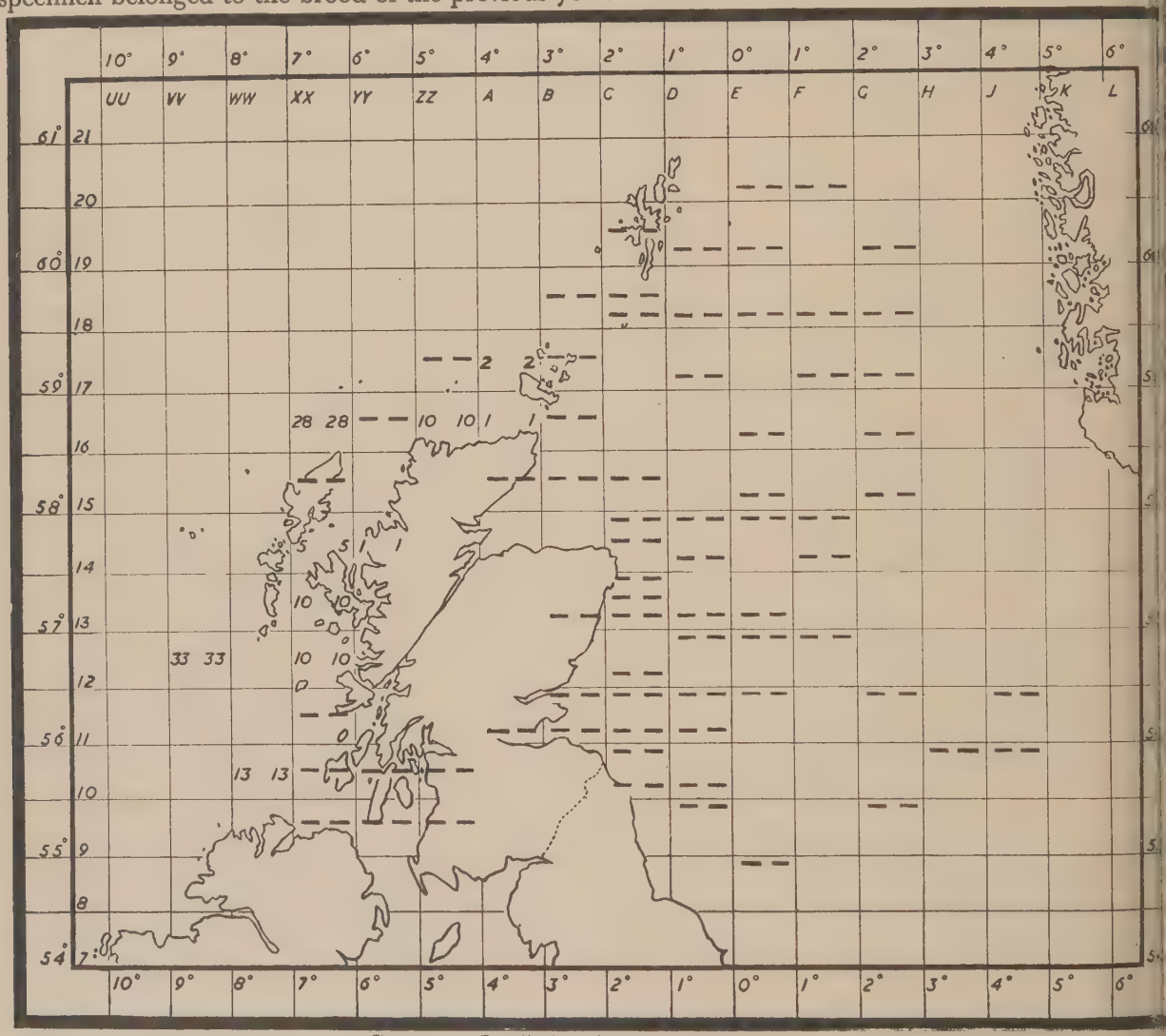

CHART 1.—*Distribution of Lemon Sole Larvæ in April.*

Total for all nets on left of each statistical rectangle with number in youngest stages (1 to 2) on right: 1929 records top row, middle, 1931 bottom. Blank hauls indicated by dashes.

April (see Chart 1): In April extensive investigations were carried out in the Central North Sea in and on the same grounds and in the Northern North Sea in 1931 with completely negative resul both years. In 1930 the first week of April was spent examining the waters adjoining the Aberdeens Coast, the Moray Firth and grounds to the north of this as far as the south end of the Shetlands, but no larvæ of the lemon sole appeared in the catches. On April 8th operations were commenced to west of the Orkneys and two larvæ were caught west of Noup Head, thus providing the earliest pos records in the three year period under review. Thereafter, larvæ were obtained in small numbe various stations in the Minch and, although none was taken during extensive townettings in the F of Clyde, they were taken in larger quantities on the offshore grounds such as in the vicinity of Sta

s, on grounds south-west of Barra Head and off the Butt of Lewis. Additional records were obtained of the Orkneys on the return journey, some specimens of which had then reached stage 2 of the lopmental series. This voyage was terminated by repeating observations in the Moray Firth and ne Aberdeenshire Coast in the last days of the month. These hauls however, revealed the continued nce of lemon sole larvæ from these waters. It seems reasonable to conclude, therefore, that spawning ie waters off the west and north coasts was earlier than in the North Sea adjoining the east coast otland. This view finds supports in some of the results obtained in the following month which will be considered.

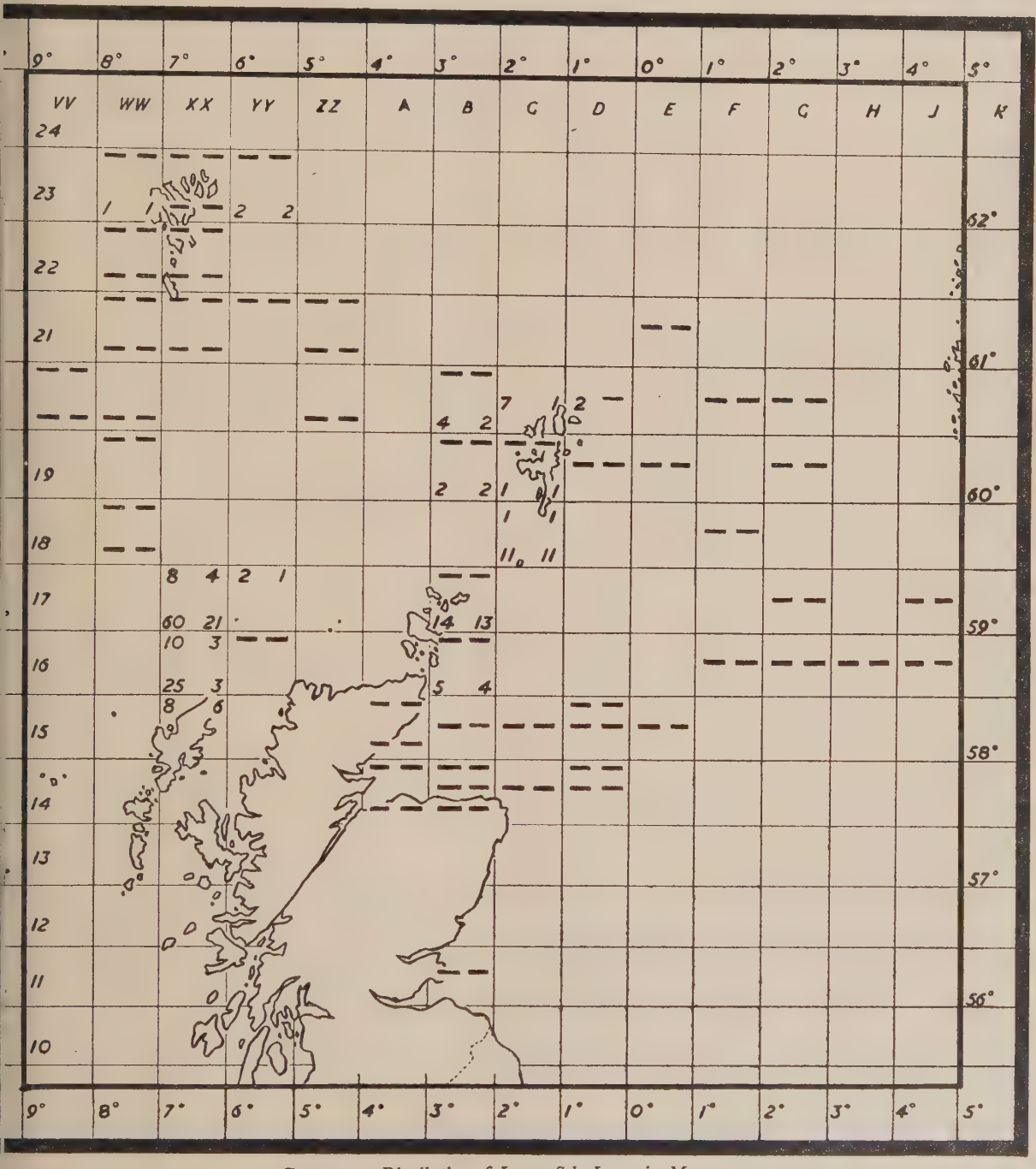

CHART 2.—*Distribution of Lemon Sole Larvæ in May.*

for all nets on left of each statistical rectangle with number in youngest stages (1 to 2) on right: 1929 records top row, 1930 middle, 1931 bottom. Blank hauls indicated by dashes.

May (see Chart 2): During the first week of May in 1929 and 1931 operations in the North Sea confined to the Moray Firth and to a line of stations running along the east coast of the Orkne Fair Isle thence continuing northwards along the west coast of the Shetlands. On both occasions l were absent from the catches in the Moray Firth up to the 6th and 10th days respectively. In 192 first positive record was obtained on 6th May when a single larva at stage 2 was taken near Fair but further operations west of the Shetlands were without success. In 1931 larvæ were first caug the eastern entrance to the Pentland Firth on 10th May and thereafter small numbers were take all the positions sampled on the line of stations leading to the northwest of the Shetlands.

In May, 1930, St. Andrews Bay was sampled on the 9th, the Aberdeenshire coastal waters on 14th and the Moray Firth from the 15th to the 20th and in each case no larvæ were caught. T results confirm the negative results obtained in the previous month of the same year and those of the week of May in 1929 and 1931. Observations were also made in the coastal section of the Nort North Sea and also off the north of Shetland where nine larvæ were caught on the last three days o mon'h. Most of these larvæ were beyond stage 2 and one had even reached stage 5. These last rec even allowing for the drift of the larvæ, show that spawning is earlier in Shetland waters than in the M Firth or adjacent grounds.

In 1929 and 1931 the remainder of the month was devoted to a survey of Faroese waters and alth stations were worked all round the islands, no larvæ were observed in 1929 and only three speci were taken in 1931, two of which were at stage 1 and one at stage 2. The return journey in each was made by way of Faroe Bank, where hauls were also blank, and the grounds to the north-w Scotland, where small numbers of lemon sole larvæ were taken on 28th-29th May, 1929, and conside larger numbers on the same dates in 1931. In 1929 the larvæ included specimens beyond stage development while in 1931 all stages from 1 to 6 were identified. These two sets of records su the conclusion arrived at in the paragraph dealing with April, that spawning is earlier on the wes north-west coasts than within the North Sea to the east of Scotland. Furthermore the more adva stages characterising the 1931 larvæ suggest that spawning in this region had started earlier in that than in 1929. Assuming the average time taken to attain stage 6 of the developmental series to be a two months and the duration of the pelagic egg period to be eight days then the most advanced l in 1931 must have developed from eggs which were spawned in the second half of March. Eviden a March spawning, even on grounds as far north as the west of Orkney, is also provided by the cap of larvæ on 8th April 1930, already referred to.

It may also be concluded that spawning at the Faroes is later than on the nearest Scottish grou at the Shetlands and north of the Butt of Lewis. The development of the few larvæ procured at the F in the years 1929 and 1931 suggests that spawning commences at the beginning of May or even i last week of April. This agrees closely with the capture of a few ripe female fish on Faroese grou April and of the first spent female in May, which were described in a previous paper (Rae 1939,b).

It is interesting to note that the first appearance of larvæ in the Northern North Sea in each o three years is at one or more of the entrances from the Atlantic—namely, the Pentland Firth, the Or Shetland Channel and at north Shetland. As larvæ were found in various places off the west coa the Orkneys and Shetlands it would seem as if the first larvæ found in the adjoining waters of the N Sea had either drifted through the connecting channels or had hatched from eggs which had ar in the same manner. It is unfortunate, however, that no plankton hauls were made in the Moray later than the first week of May in 1929 and 1931 or later than the 20th May 1930 as it is almost ce that positive records would have been obtained in that region towards the end of the month. This finds support from an examination of the developmental stages attained by the larvæ taken i following months.

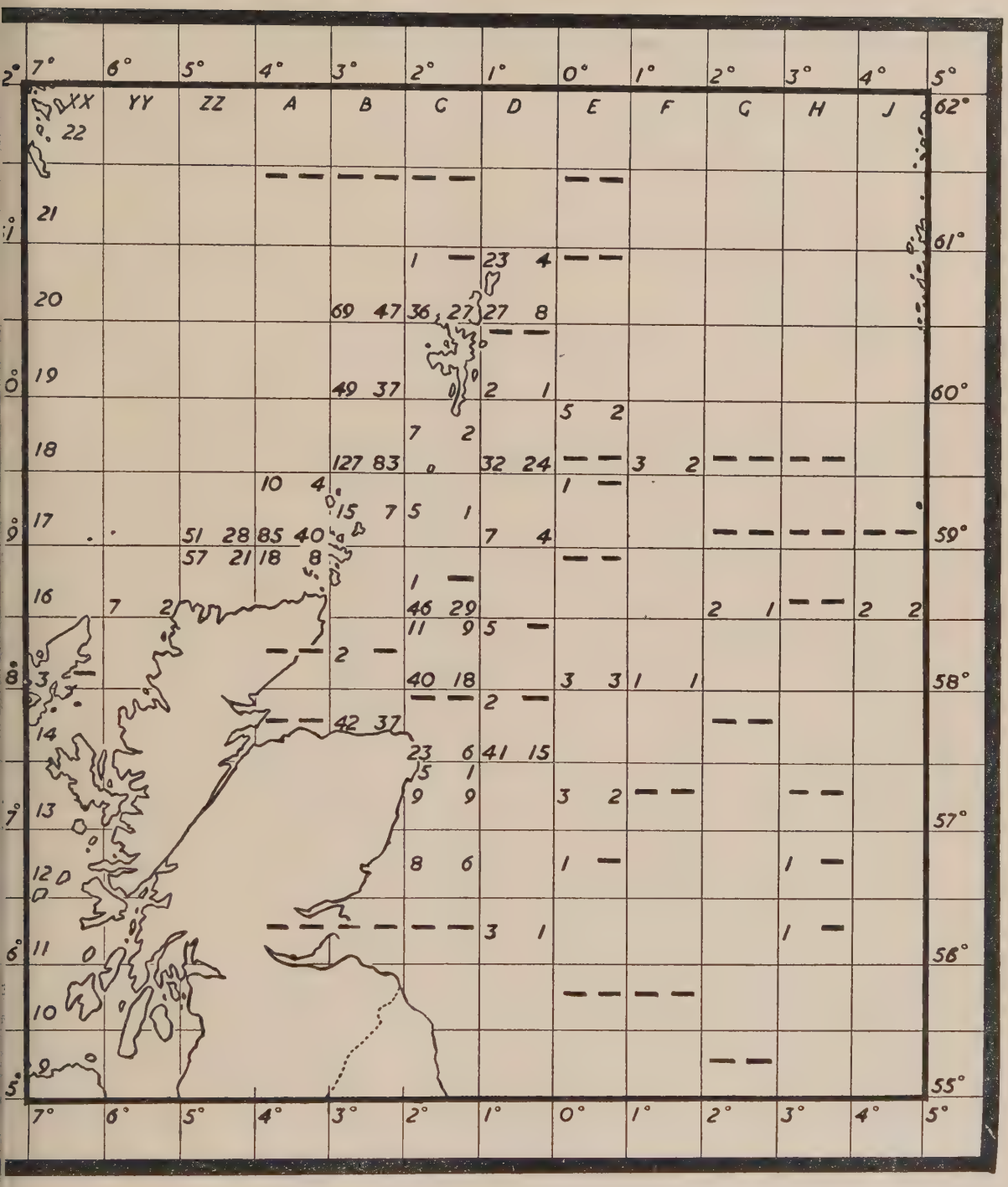

CHART 3.—*Distribution of Lemon Sole Larvæ in June.*

for all nets on left of each statistical rectangle with number in youngest stages (1 to 2) on right: 1929 records top row, 1930 middle, 1931 bottom. Blank hauls indicated by dashes.

ee Chart 3): Both the unfinished cruises of May 1929 and 1931 were resumed in the first days of y working stations along the north coast of Scotland to the Orkneys and then northwards. The in 1929 were variable but in 1931 a remarkable series of hauls was obtained from Cape Wrath gga in the Shetlands. Omitting records obtained by the Agassiz stramin, which was not used at station, the following are the numbers and percentages of the larvæ at the different stages of pment:—

Date	Locality		Developmental Stages 1 1–2 2	2–3 3 3–4	4 4–5 5	5–6 6
28 May	Sulisker to Butt of Lewis	Nos.	23	40	12	1
		%	30·3	52·6	15·8	1·3
7/8 June	Sule Skerry Noup Head	Nos.	61	35	12	—
		%	56·5	32·4	11·1	—
8 June	North of Orkney	Nos.	83	41	3	—
		%	65·3	32·3	2·4	—
9/10 June	West of Shetland	Nos.	109	31	5	—
		%	75·2	21·4	3·4	—

It is clear that progress in a north-easterly direction is characterised by the presence of l percentages of the youngest forms and lower percentages of the older stages. It can be concluded the that spawning first takes place in the extreme west, probably in the neighbourhood of St. Kilda ar Flannan Isles or even further south, and thereafter spreads rapidly in a north-easterly direction successive grounds from the Butt of Lewis to north-west Shetland.

The remaining part of June, 1929, was spent investigating the north-western section of the Sea including waters adjoining north and east Shetland, the outer Moray Firth and the Aberdee coastal grounds. Results, however, were meagre and never attained to the number taken off the coast in the same month.

The ground covered in June, 1931, was almost identical and although results were not up to obtained on the Butt of Lewis-Flugga line the numbers of larvæ were generally greater than in 1

Operations in June, 1930, commenced at Fair Isle and covered the east Orkney grounds ar Moray Firth, where small numbers of larvæ were procured at every station except the last off the Ban coast, where 42 specimens were taken. Subsequent investigations included the Aberdeenshire c waters and the Central North Sea but few larvæ were taken during the remainder of the mont completely negative results were experienced in the Firth of Forth.

Taking the north-western section of the North Sea as a whole lemon sole larvæ were more num in June 1931 than in the same month of the other two years. Some confirmation of later spawni this region than off the north coast is obtained from the following figures representing the numb larvæ in the different stages from the outer Moray Firth (between 1° and 2° W. longitude).

Developmental Stages	1 1–2 2	2–3 3 3–4	4 4–5 5	5–6 6	Total
Nos. of Larvæ	46	26	9	—	81
%	56·8	32·1	11·1	—	100·0

These records taken a week later, resemble those for the Sule Skerry-Noup Head locality given a *July* (see Chart 4): During the month of July in each of the three years operations by the Sc research vessel were confined to the north-western North Sea. Records are particularly num

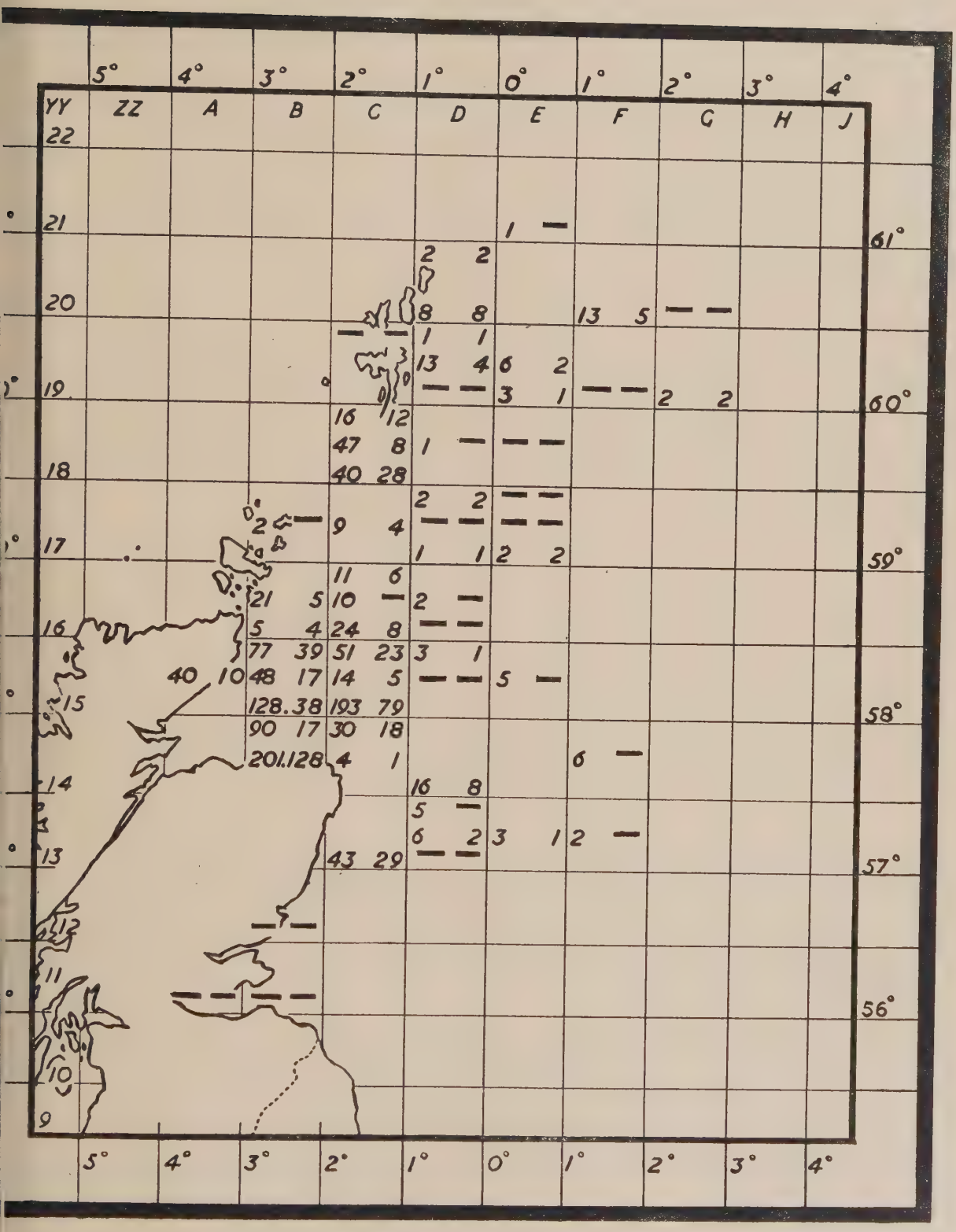

CHART 4.—*Distribution of Lemon Sole Larvæ in July.*

for all nets on left of each statistical rectangle with number in youngest stages (1 to 2) on right: 1929 records top row, 1930 middle, 1931 bottom. Blank hauls indicated by dashes.

from the Moray Firth and the adjacent waters between 1° and 2° W. longitude. In all three yea numbers of larvæ were greater in this region than in any other region hitherto considered. In the heaviest concentration of larvæ was in the southern half of the firth, along the Banffshire coast, in 1931 the records far exceeded those for 1930 in the central and outer sections of the firth. In larvæ appeared more evenly distributed over the whole area although at no point reaching the concentrations of the other years. The Aberdeenshire coast region was not sampled in 1929 and but good results were obtained in July 1931 although not approaching the density of the Moray concentrations for this month. Fair numbers of larvæ were also taken in the vicinity of Fair Isle. Firth of Forth in 1931 was found to contain no larvæ in this month. In each year small numbers of were caught throughout the north-western North Sea thus providing evidence of the widespread spa habit of this species.

The larvæ taken in the Moray Firth in July were at all stages of development, from 1 to 6. of them, naturally, were in the earlier stages but the presence of a few in stage 6, taken mainly latter half of the month, would seem to indicate that spawning commenced in the first half of May is in agreement generally with the conclusions from the previous months' records. The sequence of at all stages clearly shows that lemon soles had been spawning regularly in the Moray Firth sinc time and that it was continuing with considerable intensity. The following figures represent the po in the Moray Firth region:—

Moray Firth		Developmental Stages				Total No. of Larvæ	No. of Hauls
		1 1–2 2	2–3 3 3–4	4 4–5 5	5–6 6		
July, 1929	Nos.	98	103	45	5	251	24
	%	39·1	41·0	17·9	2·0		
July, 1930	Nos.	165	109	45	5	324	30
	%	50·9	33·7	13·9	1·5		
July, 1931	Nos.	129	168	40	13	350	16
	%	36·9	48·0	11·4	3·7		

The high percentage of the youngest stages in the 1930 records is an indication of a some later spawning in that year which will become more evident in subsequent months.

Larvæ from the Aberdeenshire coastal waters in July 1931 also exhibited various stages of develop and, although most of them were in the younger stages, two individuals were at the intermediate between 5 and 6.

Aberdeenshire Coast		Developmental Stages				Total No. of Larvæ	No. of Hauls
		1 1–2 2	2–3 3 3–4	4 4–5 5	5–6 6		
July, 1931	Nos.	27	26	4	2	59	15
	%	45·8	44·0	6·8	3·4	100·0	

These percentages, when compared with the corresponding figures for the Moray Firth, su that spawning is slightly later in Aberdeenshire waters.

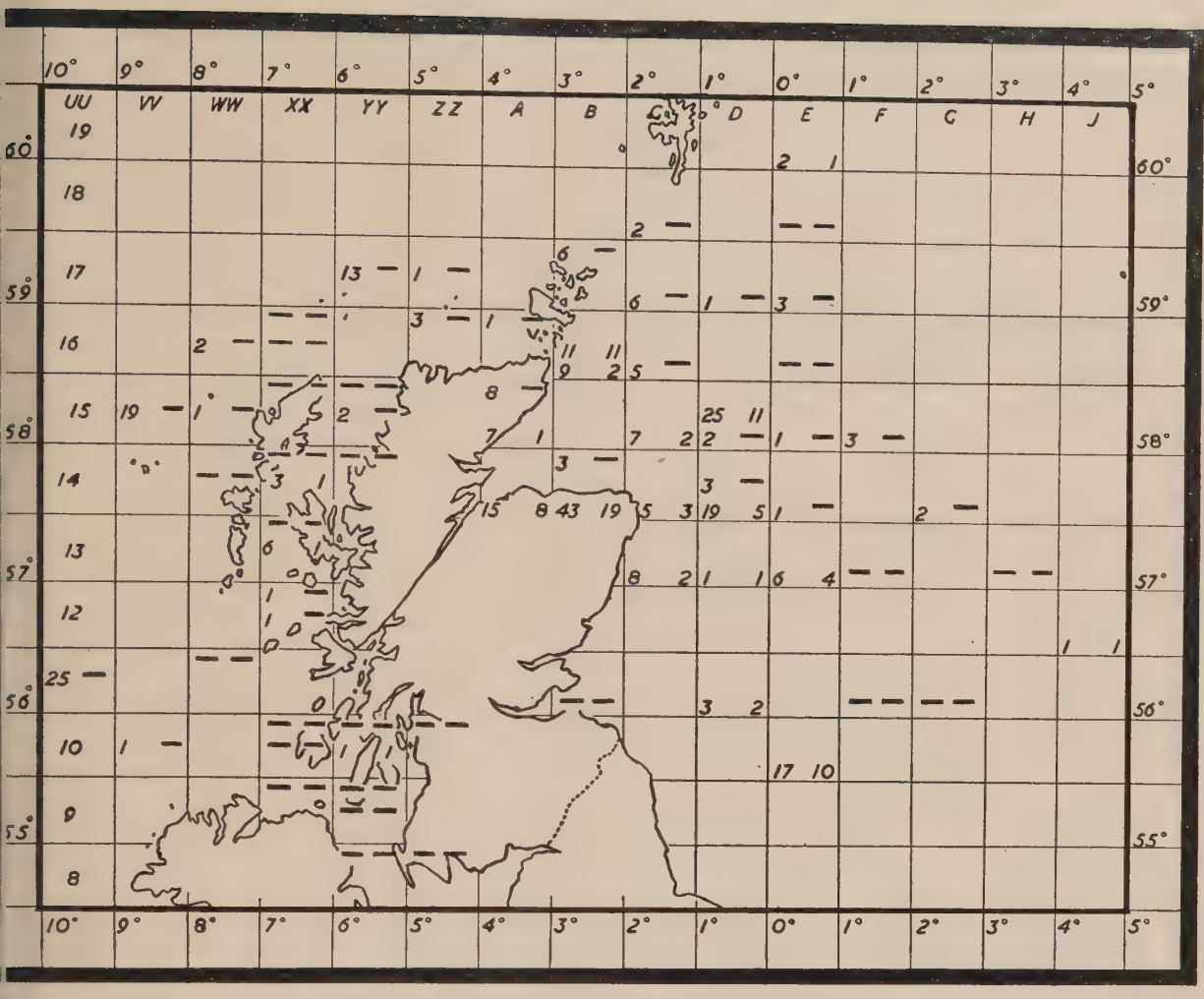

CHART 5.—*Distribution of Lemon Sole Larvæ in August.*

ıl for all nets on left of each statistical rectangle with number in youngest stages (1 to 2) on right: 1929 records top row, 1930 middle, 1931 bottom. Blank hauls indicated by dashes.

st (see Chart 5): In August 1929 and 1930 the research vessel was mainly occupied on voyages ıe north and west coasts. The records for 1929 were particularly poor and, apart from a few larvæ ı west of the Orkneys towards the end of the month, blank hauls resulted from widespread operations the Butt of Lewis through the Minch to the Skerryvore and north Irish coast grounds. Extensive ɔling in the Firth of Clyde also failed to give positive results. A single specimen, approaching stage ıs procured at the southern entrance to the Minch. In 1930 the fringes of the Aberdeenshire coast Moray Firth grounds were sampled by the research vessel outward bound for the west coast but rtunately no records are available from the main lemon sole grounds in this month. On the west : results were similar to those obtained in April of the same year with the exception that the majority e larvæ in August were at the most advanced stage of development. The youngest larvæ in these ɔles were at stage 2—the last specimen being captured in the Firth of Clyde on 18th August. It s clear from the results of 1929 and 1930 that most of the spawning on the west coast grounds is ɔleted before the end of July and the scarcity of records from the west Orkney grounds points to a tion of spawning there sometime in August.

Within the North Sea larvæ were moderately well represented in the plankton catches for August over a wide area of the Central and Northern North Sea. Again the most dense concentration within the Moray Firth, although numbers were smaller than in the previous month. The develop-ıal stages ranged over the complete series from 1 to 6, showing that spawning was still in progress

throughout the parts of the North Sea which came within the survey. The frequencies and percen within the different stages from the Moray Firth are as follows:—

Moray Firth		1 1–2 2	2–3 3 3–4	4 4–5 5	5–6 6	Totals	No. of Hauls
August, 1931 ..	Nos.	32	32	13	4	81	21
	%	39·5	39·5	16·0	5·0	100·0	

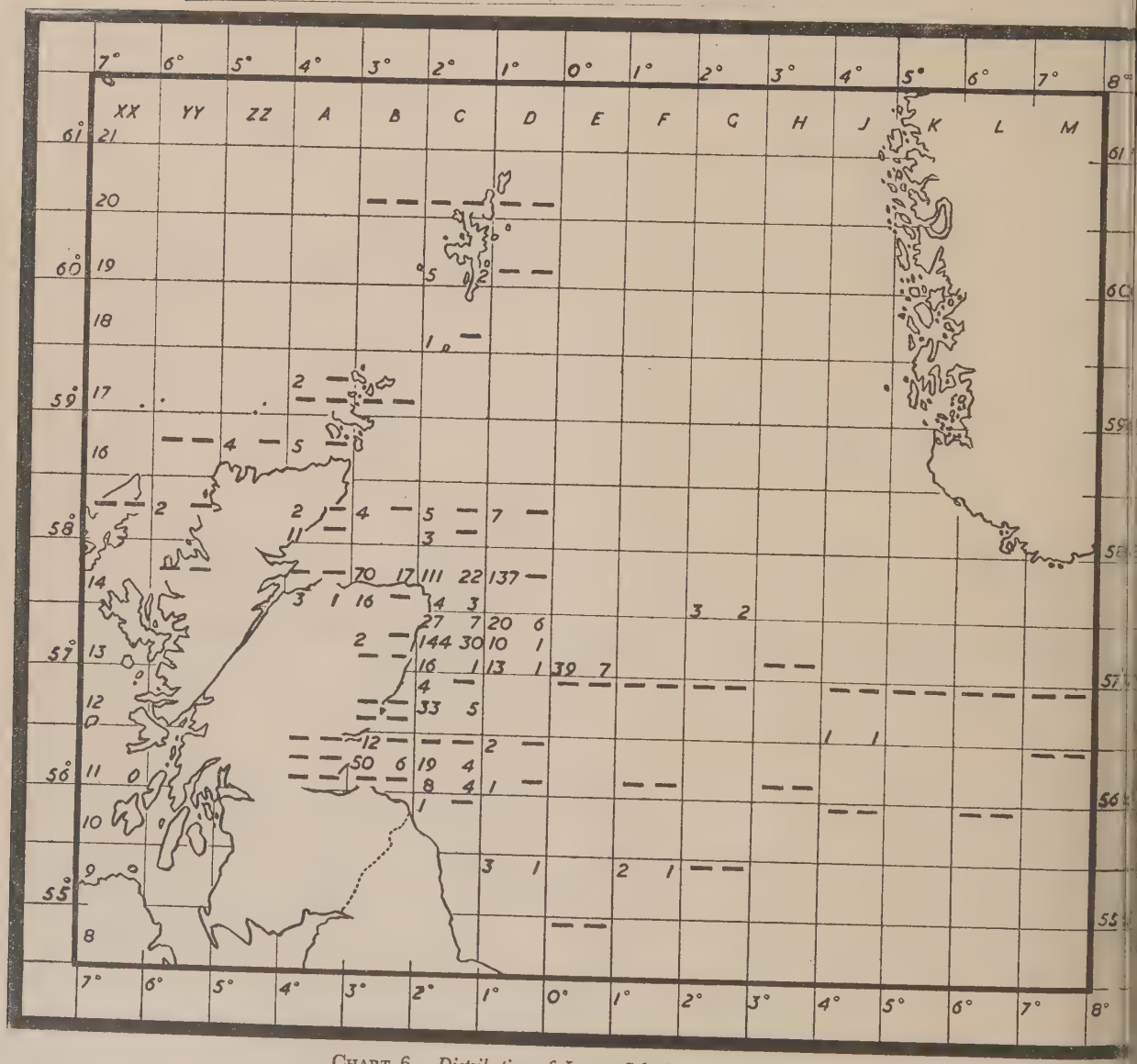

CHART 6.—*Distribution of Lemon Sole Larvæ in September.*

Total for all nets on left of each statistical rectangle with number in youngest stages (1 to 2) on right: 1929 records top row, 19 middle, 1931 bottom. Blank hauls indicated by dashes.

September (see Chart 6): In September 1929 investigations covered the Aberdeenshire coastal groun the Firth of Forth and the Central North Sea generally.

Larvæ were fairly plentiful on the first-named grounds and twelve specimens were taken in the ou and inner Firth of Forth, all of which had developed beyond stage 2. Elsewhere larvæ were spar distributed. In 1930 all grounds adjacent to the Scottish east coast were examined together with th

north coast and in the Minch. In the latter areas larvæ were scarcer than in the previous month year and, on the 5th, the last day on which positive results were obtained, all were beyond stage 2. onfirms the conclusion reached in respect of the August records that spawning off the north coast pleted some time in August. Within the Moray Firth the 1930 records show a marked decrease numbers of larvæ although a good concentration was still located off the Banffshire coast. Coming vards, however, a very dense concentration was found stretching along the Aberdeenshire coast n eastwards extension almost to the zero meridian between latitudes 57° and 58°N. Larvæ were und spreading southwards over Montrose Bank to the outer Firth of Forth although considerably nsely. These records are comparable in strength with the remarkable July records in the Moray and far exceed the numbers of larvæ taken on the same grounds in September 1929 and 1931, following table shows:—

Aberdeenshire Coast		Developmental Stages				Total No. of Larvæ	No. of Hauls
		1 1–2 2	2–3 3 3–4	4 4–5 5	5–6 6		
September, 1929 ..	Nos.	13	11	21	6	51	20
	%	25·5	21·6	41·2	11·7	100·0	
September, 1930 ..	Nos.	53	174	144	31	402	46
	%	13·2	43·3	35·8	7·7	100·0	
September, 1931 ..	Nos.	5	3	19	6	33	20
	%	15·1	9·1	57·6	18·2	100·0	

he figures indicate that spawning continues throughout the months of August and September off erdeenshire coast and that it may occur on a considerable scale as in the year 1930.

he 1931 records for September cover the Moray Firth, Shetland and Fair Isle waters, the Aberdeen-oast grounds and the western section of the Central North Sea. The figures show a further ition of the numbers of larvæ which has already been noted in August of the same year. On the ls to the west of Orkney the youngest stages were not represented in the total of ten larvae taken hus adding confirmation to the opinion that spawning in this region is over before the end of August. rvæ at stages 1 and 2 were caught near Foula (Shetlands) in the last days of September and from may be deduced that spawning in this locality may continue into the first week of this month. s at the northern end of the islands, however, gave no positive results.

r comparison with previous months the Moray Firth records for 1930 and 1931 are reproduced ws:—

Moray Firth		Developmental Stages				Total No. of Larvæ	No. of Hauls
		1 1–2 2	2–3 3 3–4	4 4–5 5	5–6 6		
September, 1930 ..	Nos.	17	31	31	9	88	42
	%	19·3	35·2	35·2	10·3	100·0	
September, 1931 ..	Nos.	1	3	4	25	33	31
	%	3·0	9·1	12·1	75·8	100·0	

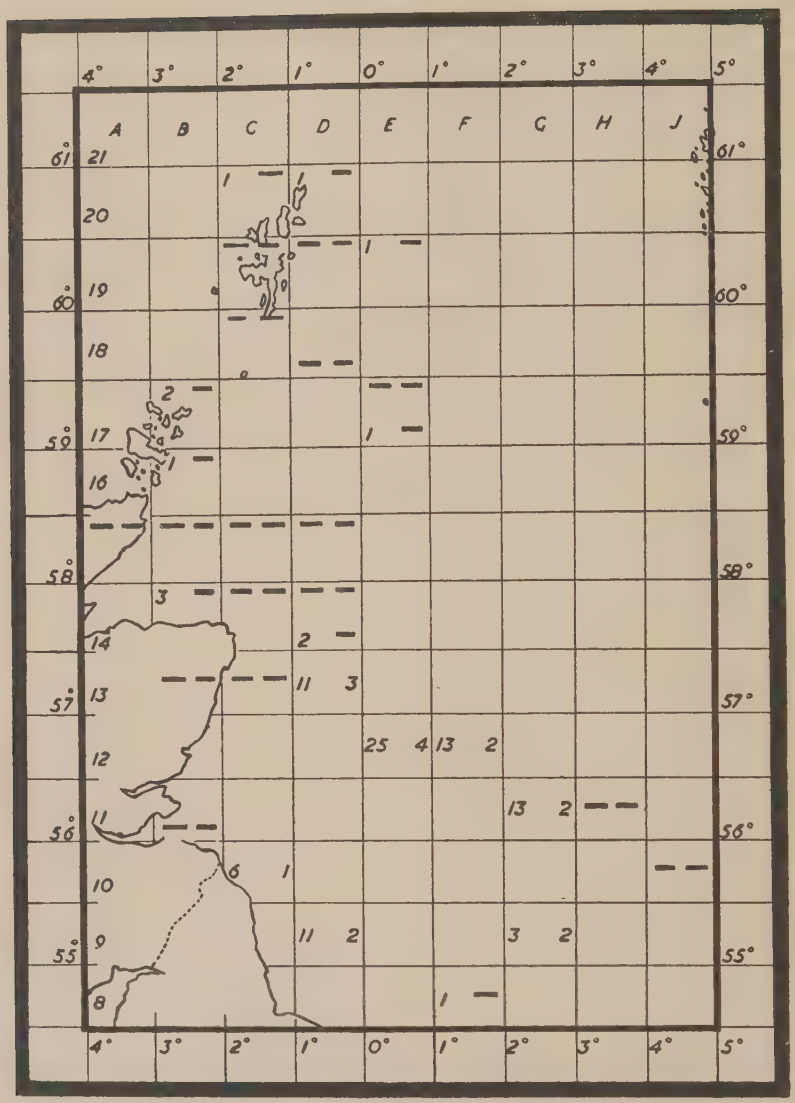

CHART 7.—*Distribution of Lemon Sole Larvæ in October.*

Total for all nets on left of each statistical rectangle with number in youngest stages (1 to 2) on right: 1929 records top row middle, 1931 bottom. Blank hauls indicated by dashes.

October (see Chart 7): Few larvæ were obtained in October 1929; those taken in the Moray Firth a east Orkney and north Shetland grounds were all in the advanced stages of development thus indi spawning in September or earlier. In 1930, October was spent investigating the Central Nort where a total of 83 larvæ was obtained in the following stages of development:—

Central North Sea		Developmental Stages				Total No. of Larvæ	No. of Hauls
		1 1–2 2	2–3 3 3–4	4 4–5 5	5–6 6		
October, 1930 ..	Nos.	16	32	24	11	83	48
	%	19·3	38·6	28·9	13·2	100·0	

The percentages in the various stages bear a close resemblance to those for grounds further in the previous month (see Moray Firth, Aberdeenshire coast—September 1930) thus suggesting a

later spawning. The youngest stages in these records clearly indicate spawning in the last week ɔtember. Sampling in the last few days of October failed to reveal any trace of the dense September :ntration off the Aberdeenshire Coast. In 1931 operations were severely curtailed by bad weather ew positive results were obtained.

t seems reasonable to conclude that spawning within the Northern and Central North Sea is y completed by the end of September, although, as records will show, it may continue into October central section.

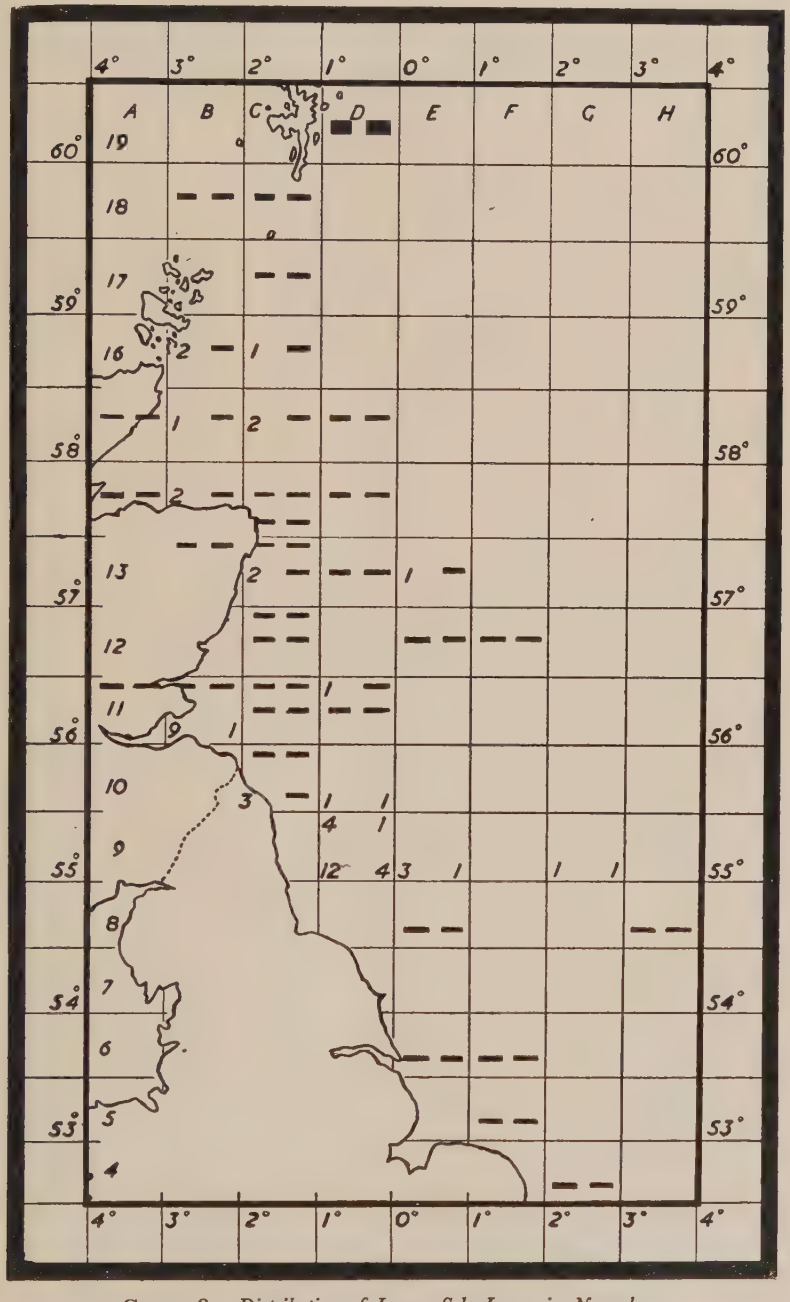

CHART 8.—*Distribution of Lemon Sole Larvæ in November.*

for all nets on left of each statistical rectangle with number in youngest stages (1 to 2) on right: 1929 records top row, 1930 middle, 1931 bottom. Blank hauls indicated by dashes.

ber (see Chart 8): Towards the end of the year deteriorating weather conditions usually hamper at sea with plankton nets but nevertheless during the years dealt with in this report, the greater

part of the most important lemon sole grounds within the North Sea was surveyed in the mo November. In 1929 and 1931 these investigations covered the Aberdeenshire coast region, th Scottish Bight, including the Firth of Forth, and the grounds lying off the north-east coast of En In the former year most of the hauls were blank and only five larvæ were caught on the more sou grounds. In 1931 hauls in the Aberdeenshire coastal waters produced no larvæ but a total of obtained in the Firth of Forth and off the north-east coast of England. It is interesting to note t both years the larvæ included some of the youngest stages, which, having regard to their date of ca clearly indicates that spawning persists into the last week of October or even the first week of Nov in the western section of the Central North Sea.

The 1930 operations were more extensive, covering the whole of the Scottish east coast fro Shetlands to the Firth of Forth. Eleven larvæ were taken, eight in the Moray Firth or adjacent and two off the Aberdeenshire coast, all of which were at stage 5 or beyond this. The Moray records, obtained early in the month, lend support to the view that spawning is completed in this by the end of September.

December: Although the research vessel continued to operate during December 1929 and 1930, co the Moray Firth, the Aberdeenshire coast waters and the Firth of Forth, no further records of lemo larvæ were obtained. Investigations in other years, however, have resulted in larvæ being found occ ally in the plankton of the inner and outer Firth of Forth as late as 20th December. The develop of these specimens was in each case beyond stage 5 thus indicating a spawning towards the end of O at the earliest.

It is now proposed to summarise the conclusions arrived at in these discussions under the appro headings.

SPAWNING PERIOD

It has been apparent for some time that the incidence of the spawning period for lemon soles considerably from place to place round the shores of the British Isles and McIntosh (1897) in his sun of the observations on this subject mentions every month from February to August as being spa months for this species. In dealing with the results of marking experiments on lemon soles an at was made to define the period for Scottish waters by the examination in the laboratory of the con of the reproductive organs of recaptured marked fish (Bowman 1935). The conclusion arrived a that although ripe male lemon soles were taken in practically every month of the year, no female ripe ovaries were recorded before April or later than September. Lemon soles caught by the res vessel but not utilised for marking experiments were also examined and it was found that the ran ripe fish was extended by about a month each way to give a season March to October for Scottish w

From the discussion of the occurrence of the larvæ in the foregoing paragraphs a more det statement of the situation can now be made. Spawning in Scottish waters clearly commences o west coast at the beginning of April or even, in some years, in the latter half of March, and ra spreads north-eastwards along the western coast of the Hebrides and through the Minch to the coast and the western side of the Orkneys and Shetlands. This early spawning is in accordance researches on the west coast of Ireland where Holt (1893) found lemon sole eggs in April, May and With regard to the termination of spawning on these grounds, it has been suggested in discussi records for August that spawning is mainly completed by the end of July so that an early termi is in conformity with the early beginning on the west coast grounds. In the waters off the north the records of larvæ taken in September indicate a somewhat later completion of spawning, to the end of August, while on west Shetland grounds it may be prolonged into the first half of Septe

The first larvæ caught within the North Sea were, in each of the three years, taken at the ea end of one or more of the entrances from the Atlantic. As already suggested in this paper, this indicate the drift of eggs or larvæ through the connecting channels from grounds to the westwards may, on the other hand, show that the spawning impulse has been transmitted from the Atlantic t nearest North Sea grounds with the advent of suitable conditions. Whatever the true explanation be it is clear that spawning commences in the northern half of the Moray Firth and its adjacent w to the eastwards in the first half of May. This is in agreement with records of the collection of l sole eggs in the Moray Firth in May by Masterman (1892) and Kyle (1897). Thereafter spawni

s to a maximum in June and July and then diminishes in intensity throughout August and September it ceases towards the end of the latter month. From the northern Moray Firth the impulse rapidly s across the Firth to the southern shore and then embraces the Aberdeenshire coastal grounds it reaches its maximum intensity slightly later than in the Moray Firth. Thus a considerable nt of spawning takes place in August in this region and the act is continued into September and even ber. From a study of the developmental stages of the larvæ caught in the outer Firth of Forth ff the north-east coast of England in November, it can be concluded that spawning in the western n of the Central North Sea may continue to the end of October or, in exceptional cases, into November. conclusions may be summarised in the following way:—

Region	Spawning		
	Beginning	Maximum	Completion
West Coast.. ..	End of March: beginning of April.	April, May.	End of July.
West of the Orkneys	End of March: beginning of April.	May, June.	End of August.
Shetlands	End of April.	May, June.	Beginning of September.
Moray Firth ..	First half of May	June, July	End of September.
Aberdeenshire Coast	Mid-May	Mid-June, July and August.	Beginning of October.
West Central North Sea	Mid-May	July, August	End of October, beginning of November.

he records of the three years, therefore, demonstrate that the spawning impulse in lemon soles ps in the west and travels north and east into the North Sea, whence it spreads southwards along the ast of Scotland. As the Scottish research vessel seldom operates further south than the north-east h coast the data under examination does not throw any light on the situation in the Southern North Reference has, however, already been made to the work of other investigators on this subject indicates an earlier season in southern waters. Thus Clark (1920) gives the spawning season in nglish Channel as February to July and Ehrenbaum (1909) gives the season in the North Sea as to September. This may indicate, therefore, that another spawning impulse, originating in the h Channel, may enter the North Sea and travel northwards and eastwards to meet the impulse g from the north.

n the case of the plaice Bowman (1914 and 1921) has shown that spawning is dependent on the rature of the water but not on the salinity. An examination of the temperatures recorded at on stations during the months of March, April and May shows that the lemon sole is also, in spawn- verned by the temperature of the water. Thus in the north-western section of the North Sea wning appears to take place until the temperature at the sea bottom has risen to about 6.5°C. s particularly noticeable in the central and outer Moray Firth and off the Aberdeenshire coast the bottom temperatures throughout March and April are generally below 6°C. (see Bulletin graphique). The rise of the bottom temperature to about 6.5°C. in May is followed immediately spawning of the lemon sole. At the same time the surface temperatures in the same waters range °C. to 8.5°C.

he temperature conditions for fish spawning in the western Central North Sea in October and nber have also been examined. Scottish hydrographical records for the three years under review bottom temperatures ranging from about 8.5°C. to about 11°C. This is considerably higher ne minimum of 6.5°C. and would therefore be suitable for late spawning and the development of

sufficient records during the months immediately preceding spawning render an appreciation position on west coast grounds more difficult but at certain positions west of the Orkneys the bottom

temperature has frequently reached 6.5°C. or higher as early as March. This would explain the spawning on these grounds.

SPAWNING PLACES

From the study of the occurrence of ripe and spawning lemon soles (Bowman 1935) it was concluded spawning may take place almost in any locality where adult fish are found. This statement is confirmed capture of larvæ throughout Scottish waters. Naturally, larvæ are infrequent where the adult popula small and numerous on the more densely populated grounds. From the occurrence of ripe and spa fish, it was also concluded that certain areas were specially favoured by spawning fish, e.g., the no half of the Moray Firth, off the Aberdeenshire Coast, off the Firth of Forth and in the vicinity of The evidence of the youngest larval stages, which alone have been considered in order to minimi error due to drift, does not confirm the existence of these separate centres of spawning activity but inc that the first two areas are part of the same large area, including the Moray Firth (but excluding the triangle) and Aberdeenshire coastal waters, bounded by latitude 58°30′N., by longitude 1°W. (a the Moray Firth), by the zero meridian (east of Aberdeenshire) and by latitude 57°N. The catc larvæ within this region are far heavier than in any other region investigated by the Scottish re vessel. Outwith this region the average numbers of larvæ per haul decrease and in the remaining se of the Central and Northern North Sea the records suffice to show that spawning does take place throu the entire area. Although some spawning occurs in the outer Firth of Forth the concentration of does not suggest that this area is particularly favoured as a spawning ground. Indeed the numb larvæ indicate that the outer firth is of less importance for spawning than the grounds east of Mo which lie at the southern end of the main spawning area referred to above.

Larvæ are comparatively scarce off the east coast of the Orkneys and accordingly it must be con that spawning is not common in this locality. They appear in greater numbers near the Fair Isl suggesting that spawning is prevalent in the vicinity. Some of these larvæ may, however, be d from the extensive spawning area stretching from the Butt of Lewis to West Shetland which was d strated so clearly by the investigations of May-June 1931 and also to some degree by those of Ma 1929. It is unfortunate that these waters were not sampled in May or June of 1930 in order to p additional confirmation. In view of the capture of large numbers of larvæ at regular intervals fro Butt of Lewis to Flugga, it seems reasonable to suppose that the samples were from one conti concentration which may have extended south-west from the Butt of Lewis to the Flannan Isles a Kilda. Having regard to the configuration of the sea bottom in this region it is probable that the spa ground is in the form of a narrow belt stretching from St. Kilda beyond the Butt of Lewis to the of Shetland, but in view of the distance between the extreme stations these grounds must be consi as ranking next in importance to the Moray Firth—Aberdeenshire coast region. Although the nu of larvæ taken per haul are only slightly smaller than those from the Moray Firth, there is no evi that the season in the north-west region continues for the same length of time as in the main Nort spawning region. Further investigations are therefore desirable to ascertain the true significa this region as a spawning centre.

The position on other west coast grounds is not clear as visits by the research vessel during 19 were few and the exact location of the spawning grounds cannot be accurately defined. Spa however, occurs throughout the Minch and on west coast grounds generally with concentrations known dimensions at points in the deeper water (over 100 metres) e.g., in the vicinity of Stanton south-west of Barra Head and in the St. Kilda-Flannan Isles area. It also occurs in the Firth of but from the records of the capture of young lemon soles off the Ayrshire Coast and in Luce Bay clear that some spawning concentration is located in this region which is not evident from the re of the larvæ.

Although larvæ, including the youngest stages, have been captured in shallow waters such a Dornoch Firth, the Firth of Forth (McIntosh, 1890, records the collection of eggs in Aberlady Broad Bay (Isle of Lewis) and Moonen Bay (Skye), it is doubtful if much spawning takes place in and it is more probable that the larvæ in question were carried into the bays by currents from n spawning grounds.

DISPERSAL OF EGGS AND LARVAE

o study of the spawning place of any species can be regarded as complete without taking account action of the sea currents in distributing the eggs and larvæ. Before dealing with the records of sole larvæ from this viewpoint it is proposed to examine the action of currents in a more general It is already recognised that the eggs and larvæ of certain species are carried considerable distances : prevailing currents. The extent of the dispersal must, however, be dependent on a number of erations:—

') the time between the spawning of the eggs and the hatching of the larvæ,
') the vertical distribution of the eggs in the water layers,
) the duration of the planktonic life of the larvæ,
!) the vertical distribution of the larvæ in the water layers,
) the season of the egg and larval development,
) the distribution of the eggs and larvæ relative to the major and subsidiary currents.

owman (1914 and 1921), in dealing with the distribution of plaice eggs in the Northern North as shown that the eggs of the species are at first located at the surface but that their specific gravity as the embryo develops and that later they sink in deeper water layers where the larvæ hatch out. ailed study of the development of lemon sole eggs has so far been made but in view of the depths o m.) at which most of the larvæ, including the youngest stages, are found, it seems more than ole that a similar descent of the eggs to deeper water takes place in the case of this species. The ance of these matters becomes clear when it is recalled that the surface currents in the North Sea eighbouring waters vary according to the time of year and that the surface currents have a much r velocity than the water layers immediately above the sea bottom. Tait (1930) has shown that face currents vary from a maximum velocity of from 12 to 13 miles per day in the late spring and ummer to a minimum of from 5 to 6 miles per day during the winter months. With regard to the n currents, Brown (1913) has shown that these are considerably slower and that in the Moray Firth ary on an average from 3 to 22 miles in each 100 days although more recent researches by R. E. as yet unpublished, indicate a somewhat faster rate of flow. Presumably the bottom currents ry seasonally but the effect is probably negligible in this case. It is clear therefore that the longer oat at the surface the further will they be carried from their place of origin. Furthermore, the the spawning time to the season of the maximum surface current velocity the further will the eggs ried in a relatively short time.

n the case of the lemon sole, therefore, eggs shed in June would, from the time of reaching the surface pt along at the maximum speed of the current and would, if the development of the larvæ were ged, be rapidly carried far from their place of spawning. As McIntosh has shown, however, the pment of the lemon sole embryo is comparatively quick and the larva emerges on the eighth day or, favourable conditions, on the sixth day. Meanwhile any change in the eggs which may cause o sink to deeper water layers would inevitably reduce the speed and the distance of their dispersal. g regard to the lack of information on the development of the lemon sole egg, no accurate estimate made at this time of the distance the eggs are dispersed. In view of the depths at which the larvæ however, it is clear that their dispersal by the bottom currents cannot be great even in localities the maximum bottom velocity prevails.

nally the subsidiary current systems in the region of the greatest spawning activity for lemon soles n important role in the dispersal of the eggs and larvæ. The chief spawning region in the Moray nd Aberdeenshire Coast grounds lies on the western side of the main south-going current in the Sea. This, one would expect, would carry the eggs and larvæ southward away from the spawning ls and to some extent this is, no doubt, true. Thus, from grounds in the northern half of the Moray ggs and larvæ are carried southwards deeper into the Moray Firth and towards the Aberdeenshire Within the Firth, however, it has been shown that an eddy operates which produces a current g along the coast of Sutherland and Caithness in a north-easterly direction (Tait 1930). It is obvious re that this eddy must act in a compensatory manner and so return eggs and larvæ spawned the Firth or previously swept into it from the outer regions to the more northerly grounds. In

support of this view there are abundant records of larvae at all stages of development on the n Moray Firth grounds where ripe and spawning fish have been found concentrated. Similarly, e larvæ on the Aberdeenshire coastal grounds tend to be swept southwards but again an eddy— occasion the mid-east Scottish eddy (Tait 1930)—operates so as to carry eggs and larvæ along th of Angus and Kincardineshire in a north-easterly direction from the outer Firth of Forth and inte grounds to the waters off the Aberdeenshire coast. Outwith the scope of these eddies eggs an are undoubtedly dispersed to the southwards, but the distance involved is probably limited of the rapid development of the embryo and the possibly brief surface existence of the egg.

VERTICAL DISTRIBUTION OF THE LARVAE

Table 1 shows that the deepest or bottom net of the three one metre townets caught mor than the others (62% to 72% of the total taken by the three nets) and that few were found in the collections (2% to 4% of the total). In order to examine in more detail the depths at which th occur the one metre townet records for the three years have been combined, while at the sam distinction has been drawn between hauls made in daylight and those in darkness for the pur studying any diurnal vertical movement. Each townet haul has been assigned to its appropriat depth zone from the surface downwards and the results are set forth in Table 5, the various colu which are self explanatory.

TABLE 5

Vertical Distribution of Lemon Sole Larvæ from one metre Townet Collections, 1929-1931

(a) *Daylight*—0600-1800 hours G.M.T.

Depth m.	No. of Hauls	Developmental Stages, No. of Larvæ				Developmental Stages, No. per 10 hauls.				Smoothed in threes	% of Total
		1-2	2/3-5	5/6-6	Total	1-2	2/3-5	5/6-6	Total		
Surface ..	112	0	3	0	3	0	+	0	+	0	0·0
1–10 ..	1	0	0	0	0	0	0	0	0	3	0·7
11–20 ..	12	2	7	0	9	2	6	0	8	7	1·6
21–30 ..	17	13	10	0	23	8	6	0	14	20	4·7
31–40 ..	38	86	57	2	145	22	15	1	38	25	5·8
41–50 ..	57	83	50	3	136	14	9	1	24	36	8·4
51–60 ..	9	16	24	0	40	18	27	0	45	43	10·0
61–70 ..	19	40	72	4	116	21	38	2	61	65	15·1
71–80 ..	15	62	72	1	135	41	48	1	90	78	18·1
81–90 ..	11	17	68	5	90	15	62	5	82	79	18·4
91–100 ..	41	145	101	20	266	35	25	5	65	74	17·2
Totals	332	464	464	35	963	176	236	15	427	430	100·0

(b) *Darkness*—1800-0600 hours G.M.T.

Depth m.	No. of Hauls	Developmental Stages, No. of Larvæ				Developmental Stages, No. per 10 hauls				Smoothed in threes	% of Total
		1-2	2/3-5	5/6-6	Total	1-2	2/3-5	5/6-6	Total		
Surface ..	95	18	19	13	50	2	2	1	5	2	0·5
1–10 ..	0	0	0	0	0	0	0	0	0	7	1·8
11–20 ..	6	7	2	0	9	12	3	0	15	19	5·0
21–30 ..	14	34	22	4	60	24	16	3	43	25	6·6
31–40 ..	30	22	27	4	53	7	9	1	17	28	7·4
41–50 ..	53	79	46	7	132	15	9	1	25	22	5·8
51–60 ..	10	7	18	0	25	7	18	0	25	29	7·7
61–70 ..	13	13	22	1	36	10	17	1	28	61	16·1
71–80 ..	13	73	91	6	170	56	70	5	131	69	18·2
81–90 ..	4	8	9	2	19	20	23	5	48	73	19·3
91–100 ..	47	75	100	11	186	16	21	3	40	44	11·6
Totals	285	336	356	48	740	169	188	20	377	379	100·0

he columns in Table 5 giving the numbers caught per ten hauls and the percentages show that væ are sparsely distributed at the surface and in the upper water layers to a depth of about 30 metres. after, with increasing depth, the larvæ become more numerous until the zones containing the greatest rs are reached at 51 to 100 metres. The cumulative percentages in the final column of each half table indicate that about one quarter of the larvæ were caught from the surface to a depth of 50 while the remaining three-quarters were taken from the latter depth to 100 metres.

o horizontal hauls with townets were made at depths below 100 m. but the Agassiz stramin gear ed at greater depths in combined half-hour hauls, consisting of ten minutes each at the bottom, -water and at the surface. Larvæ were taken in this way over a wide depth range from 20-10-0 m 85-0 m. and three specimens were taken in an isolated haul at 250-125-0 m. The Agassiz records een classified according to depth as follows:—

Depth of hauls in metres.	20–10–0 to 40–20–0	50–25–0 to 100–50–0	110–55–0 to 170–85–0 and 250–125–0
No. of larvæ ..	25	1057	205
%	2%	82%	16%

ven if allowance is made for a rather higher number of hauls from the middle depths the figures a preponderance of larvæ from these depths. Due to the nature of the hauls the second column nclude a number of larvæ taken in zones from the surface to 50 m., but having regard to the small rs in the first column and to the relative scarcity of larvæ in the one metre townets from the surface n., the larvæ taken in the Agassiz stramin above 50 m. can amount to only a fraction of the total at the majority are from the deeper zones from 51-100 m. These Agassiz records are therefore ed as helping to confirm the conclusions from the tow-nets.

is equally clear that of the 205 larvæ in the third column a number must have been taken in water han 100 m. depth. Only one-third of the time spent in fishing for the 205 larvæ was actually l to depths below 100 m., while another third of the time was spent at depths ranging from 51 m. Assuming, therefore, that the larvæ were present in the normal proportions at these depths tain that a fairly big proportion of the 205 larvæ were caught above 100 m., thus considerably g the number caught below 100 m. in depth. It must be concluded, therefore, that although sole larvæ are found at depths greater than 100 m. the numbers decline sharply with increasing nd that it is doubtful if any larvæ are present below 150 m.

e various developmental stages have been arranged in three groups in Table 5 in order to study sible differences in the vertical distribution, but no particular trend can be detected in this case ordingly it must be assumed that larvæ of different ages are not segregated by depth to any marked

e separation of daylight records from those obtained during darkness has perhaps been decided her artificial basis—daylight 0600 to 1800 hours G.M.T., darkness 1800 to 0600 hours—in view of daylight throughout the summer in Scottish waters but the method is convenient for the present .

e number of larvæ taken at the surface in daylight, 3 in 112 hauls, is in marked contrast to the taken there during darkness, 50 in 95 hauls. The three specimens caught at the surface in daylight l taken before 0900 hours G.M.T., i.e., in the three hours immediately following the period of s. One of these was recorded in June, the other two in July. The developmental stages have once een kept separate in order to demonstrate any possible difference in the behaviour of the larvæ ge, but again no consistent difference can be observed from one group to another. Each group n upward movement of the larvæ with the onset of darkness and a downward movement with the h of daylight; this movement becomes more impressive if all developmental stages are combined. nination of the cumulative percentages in the various depth zones suggests that the average extent ertical movement is not great and is probably in the region of 10 to 20 metres. Lemon sole larvæ

therefore exhibit diurnal vertical movements similar to those already demonstrated by Johanse and by Russell (1925 and 1926) for the young of other species of fish.

BROOD FLUCTUATIONS

In an earlier paper (Rae 1939a) it has been shown, from the age analysis of adult fish in lat that the year 1930 produced the most successful lemon sole brood in the period between the tw wars. In the same way it has been demonstrated that the 1929 brood showed the poorest su all the broods in the same period and that the 1931 brood also came within the poor survival c In the light of this knowledge, therefore, it is interesting to study the relative density of the larvæ years. Table 1 already shows the total number of larvæ caught each year and the number made in the months yielding positive results together with the number of positive hauls.

To enable comparison of the different years the catch per 100 hauls has been calculated net from the figures in Table 1. The results are reproduced in Table 6. From the two metre che records the 1931 brood appears three times stronger than the 1930 brood which in turn appea

TABLE 6

Lemon Sole Larvæ—Numbers per 100 hauls

Year	Net	Developmental Stages			Totals
		1–2	2/3–5	5/6–6	
1929	2 m. ch. cl.*	3	6	1	10
	1 m. ch. cl. (surface)	2	2	0	4
	,, ,, ,, (mid-water) ..	46	37	5	88
	,, ,, ,, (bottom)	49	97	3	149
	Ag. stramin	6	54	7	67
	All nets	26	43	3	72
1930	2 m. ch. cl.	40	35	2	77
	1 m. ch. cl. (surface)	2	2	2	6
	,, ,, ,, (mid-water) ..	45	17	2	64
	,, ,, ,, (bottom)	43	64	13	120
	Ag. stramin	82	236	37	355
	All Nets	42	69	11	122
1931	2 m. ch. cl.	132	87	7	226
	1 m. ch. cl. (surface)	5	6	3	14
	,, ,, ,, (midwater) ..	61	45	2	108
	,, ,, ,, (bottom) ..	137	126	7	270
	Ag. stramin	51	167	39	257
	All Nets	80	83	10	173

* m. ch. cl. = metre cheese cloth.

seven to eight times stronger than that of 1929. The one metre townets also indicate the superior of the 1931 brood over the other two years but in this case the 1929 brood appears slightly more n than that of 1930. In the Agassiz stramin records, however, the 1930 brood appears the strong the 1931 brood a close second and the 1929 a weak third in the ratio of 5 : 4 : 1. The results f different nets are thus at variance with each other although the combined records from all nets a slight predominance of the 1931 brood over that of 1930 with 1929 rather poorer than 1930.

A more detailed study of the records from areas where larvæ were found in greatest densit to reveal any more marked agreement as to the relative overall strengths of the three broods. Co ation of the subject on the basis of the developmental stages also failed to throw any more light question. Although there is some evidence to show that in 1930 the proportion of the oldest sta greater towards the end of the year the numbers on the whole are too small to be of any signific

Over the whole Scottish area the strength of the 1930 brood of lemon soles in later years was est as being three to four times greater than either of the 1929 or 1931 broods. The records of the occ of the larvæ, generally, give no indication of a correlation between their numbers and the sub

th of the broods in the lemon sole stocks. There is some evidence that the proportions of the larvæ al grounds off the Butt of Lewis and on grounds off the Aberdeenshire Coast and in the western ı of the Central North Sea do bear some relation to the brood strengths in later years but in other s, for example, from Cape Wrath to Shetland and in the Moray Firth, the numbers of larvæ appear in inverse ratio to those of the adult fish. Although the larvæ were in dense concentration on the r grounds in June 1931, the subsequent scarcity of adult fish of this brood on these and on other sh grounds suggests that large numbers of larvæ must have perished. On the other hand the 1930 , which was only moderately plentiful in the larval state in the Moray Firth in July, resulted in a sful recruitment to the stocks in that area comparable with the good recruitment of the same brood ore southerly grounds (Aberdeenshire coast and west Central North Sea) where the density of the was found to be relatively high in September.

t appears, therefore, that while fluctuations in the numbers of larvæ occur both locally and over areas, from year to year, whether as the result of unequal spawning efforts or of the destruction æ in their early stages, it does not follow that large concentrations of larvæ will foreshadow out- ng recruitment to the stocks in every instance. As the 1931 records have shown, a good crop of may give rise to poor recruitment. Moreover a moderate concentration of larvæ, given favourable ions for development, may result in a successful recruitment. Time and place, together with the ling local physical conditions and the supply of suitable food appear to be the factors which deter- he success or failure of a spawning. The data at present under review, however, are insufficient further study of this subject although it is interesting to note in connection with the good survival 1930 brood that sea temperatures were higher in September, 1930, in the Moray Firth and in the l waters of Aberdeenshire than in either of the other two years. The average temperatures for tations in the statistical rectangles C.13, D.13 in each year as derived from the Bulletin Hydro- ique were as follows:—

	1929	1930	1931
Surface	12.59°C	13.01°C	11.46°C
Bottom	11.38°C	11.46°C	10.74°C

is perhaps appropriate at this point to refer to a feature of the 1930 lemon soles which was observed mining samples of scales from fish of this brood. In a previous paper (Rae 1939a) it has been shown percentage of lemon soles in certain broods appear to pass the first winter of their existence without g a closed phase or winter ring on their scales. It has also been shown that the 1930 brood was those with a larger proportion of fish in this category. A reasonable explanation of this phenomenon , therefore, in the light of our knowledge of the 1930 larvæ, appear to be that the fish which do not t the first winter ring on their scales are those resulting from late spawning—in September or October ch does not give time for the complete development of scales before the first winter. The successful al of the 1930 brood in September and October is in accordance with this view.

AVERAGE SIZES OF THE LARVAE

ı addition to the determination of their developmental stages the larvæ were measured to the t half millimetre and average sizes have been calculated for the various regions month by month. 1931 data (Rae 1938) little or no variation on the average sizes for the different stages was observed ne region to another, but subsequent investigations do not confirm this and indeed show that small ons do occur although this may to some extent be due to differences in the time of the observations. ature noted in working with the 1931 material was a definite diminution in the average size of tage in each region from the first month after spawning until the last month in which larvæ were ed. Although there is evidence of this on all grounds, it is seen most clearly in the case of the Moray nd Aberdeenshire Coast grounds which provide the most complete records from June to September. 7 gives the numbers of larvæ in each stage, together with their range in size and the average, and demonstrates the small but definite reduction in the maximal and minimal sizes and the average season progresses. In the older stages the diminution amounts to as much as 2 to 3 millimetres.

TABLE 7

Average Sizes in Millimetres of Larval Lemon Soles in Moray Firth-Aberdeenshire Coast Regions

1929-1931

Stage		June	July	August	September	Diminution from June to Sept. (mm.)
1	No.	11	3	3	—	0·3
	R.	4·5– 6·0	4·5– 5·5	5·0– 5·5	—	
	M.	5·5	5·2	5·2	—	
1/2	No.	44	165	29	30	0·3
	R.	5·5– 8·0	4·5– 8·5	5·5– 8·0	5·5– 7·5	
	M.	7·0	6·8	7·2	6·7	
2	No.	83	258	48	63	0·3
	R.	6·0– 9·5	6·0–10·0	7·0– 9·5	6·0– 9·5	
	M.	8·2	8·2	8·2	7·9	
2/3	No.	32	110	19	51	0·7
	R.	7·5–10·5	7·5–10·5	8·0–10·5	7·0–10·5	
	M.	9·4	9·1	9·1	8·7	
3	No.	29	209	35	98	1·2
	R.	9·0–12·0	7·5–11·5	8·5–11·5	7·5—11·5	
	M.	10·6	9·8	9·9	9·4	
3/4	No.	19	104	19	123	1·6
	R.	9·5–13·5	8·5–12·5	8·5–12·0	8·5–12·5	
	M.	11·8	10·5	10·7	10·2	
4	No.	11	88	14	126	1·7
	R.	11·5–13·5	8·5–14·0	10·0–13·5	8·0–13·0	
	M.	12·8	11·6	11·7	11·1	
4/5	No.	12	39	11	61	2·3
	R.	11·5–15·5	10·5–14·5	10·5–14·0	9·5–13·5	
	M.	13·9	12·7	12·6	11·6	
5	No.	7	21	3	54	2·6
	R.	13·0–16·0	11·0–17·5	10·5–14·0	9·5–15.0	
	M.	15·3	14·1	11·8	12·7	
5/6	No.	2	14	7	23	1·8
	R.	15·0–16·5	14·5–17·0	12·5–15·5	11·5–17·5	
	M.	15·8	15·9	13·9	14·0	
6	No.	1	12	13	52	2·4
	R.	18·5	17·0–23·5	14·0–23·0	11·5–25·0	
	M.	18·5	19·2	18·3	16·1	

It is interesting to recall that Ehrenbaum (1909) has shown that a similar diminution in the a diameter of lemon sole eggs takes place from April and May to July and August. Two suggestions possible in explanation of the diminishing average sizes of the larvæ:—

(*a*) that larval growth is at a maximum early in the season and gradually falls away towards t of the year,

(*b*) that development through the various stages is speeded up relative to the rate of growth.

It is possible, however, that both explanations play a part in producing the feature in questio should perhaps also be mentioned that in areas where the number of larvæ is exceptionally large the tendency for the average sizes at the various stages to be slightly smaller than on grounds whe larvæ are sparsely distributed.

DISTRIBUTION OF THE MOST ADVANCED LARVAE IN ELATION TO THE OCCURRENCE OF THE YOUNGEST BOTTOM STAGES

eference has been made on a previous occasion (Rae 1939a) to the scarcity of records of the youngest stages of the lemon sole. Up to the end of 1936 only 98 lemon soles of less than two years of age en caught by the Scottish research vessels in Scottish waters over a period of 15 years. Since that ip to the end of 1951, the number has grown to 217. All these fish, except for a few caught in the z trawl, were taken in the small mesh cover of the cod-end of the otter trawl. Of the total only cimens belonged to the O Group. This scarcity of the youngest bottom stages has been noted by s research workers who, on the evidence of the capture of small lemon soles on certain inshore ls, have inferred that the first years of life of this species are spent in shallow water. The writer, er, has shown that the distribution of lemon soles of less than two years of age closely resembles the adult fish (1939a).

onsideration of the lemon sole larvæ now provides an opportunity of studying the change-over ie pelagic to the demersal way of life and of ascertaining where and at what depths the young fish the bottom. For this purpose the records of the larvæ identified at stage 6 of the developmental iave been specially examined. It should be remembered, however, that for the purpose of this tage 6 has been regarded more as a comprehensive group including a wide range of larvæ in the etamorphosis.

TABLE 8

Size Frequency of Lemon Sole Larvæ at Stage 6 of Development

n mm.	11	·5	12	·5	13	·5	14	·5	15	·5	16	·5	17	·5	18	·5	19
l.	—	—	—	—	—	—	—	—	1	—	1	—	1	2	1	—	1
1 m. ch. cl. ..	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
r ,, ..	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—	1	1
,, ..	—	-	—	—	—	—	—	—	—	1	1	3	5	2	6	1	2
tramin	—	1	—	4	—	2	3	5	6	12	7	3	2	9	5	10	7
otal	—	1	—	4	—	2	3	5	8	13	9	8	8	13	12	12	12

n mm.	19	·5	20	·5	21	·5	22	·5	23	·5	24	·5	25	·5	26	·5	27	·5
l.	—		2	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—
1 m. ch. cl. ..	—		1	—	—	1	1	1	2	—	—	—	—	—	1	1	—	—
r ,, ..	1		1	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—
,, ..	4		—	4	1	3	—	2	2	2	—	—	—	—	—	—	—	—
ramin	4		8	1	4	1	3	1	2	2	2	1	2	—	—	—	—	1
tal	9		12	6	5	5	4	5	8	4	2	1	2	—	1	1	—	1

ble 8 gives the size frequencies in half millimetres of all larvæ in the final stage of development. de range in size is remarkable but it should be noted that many of the individuals in the lower of the range were obtained towards the end of the year when, as shown in the previous section eport, the average size for each developmental stage diminishes as the season progresses. It may med, therefore, that towards the end of the year lemon soles take to the life on the bottom at a size than those hatched early in the year. This, combined with an examination of the average the younger stages (Table 7), leads to the conclusion that larvæ enter stage 6 on an average 1 15 and 16 mm. in length and, judging by their complete disappearance from the plankton at n., that most of them have taken to the bottom before reaching the latter size. The capture majority of the most advanced larvæ in the bottom water layers and of a higher proportion of the the Agassiz stramin net which fishes closer to the bottom than the others (see Table 8), also suggests tamorphosis is, in general, accompanied by a gradual approach of the larvæ to the sea bottom ill in the pelagic state.

Nevertheless, considerable growth clearly takes place in passing through stage 6 and some inc may prolong their pelagic existence. There is evidence that some larvæ pass the first winte pelagic state. For example, there is on record a lemon sole without scales which was taken in the townet in February and McIntosh records the capture of a larva measuring 27.5 mm. at the of the outer Firth of Forth in May 1890. He assumes that this specimen was the result of spa August of the previous year and that at capture it was about nine months old. As it has been sh

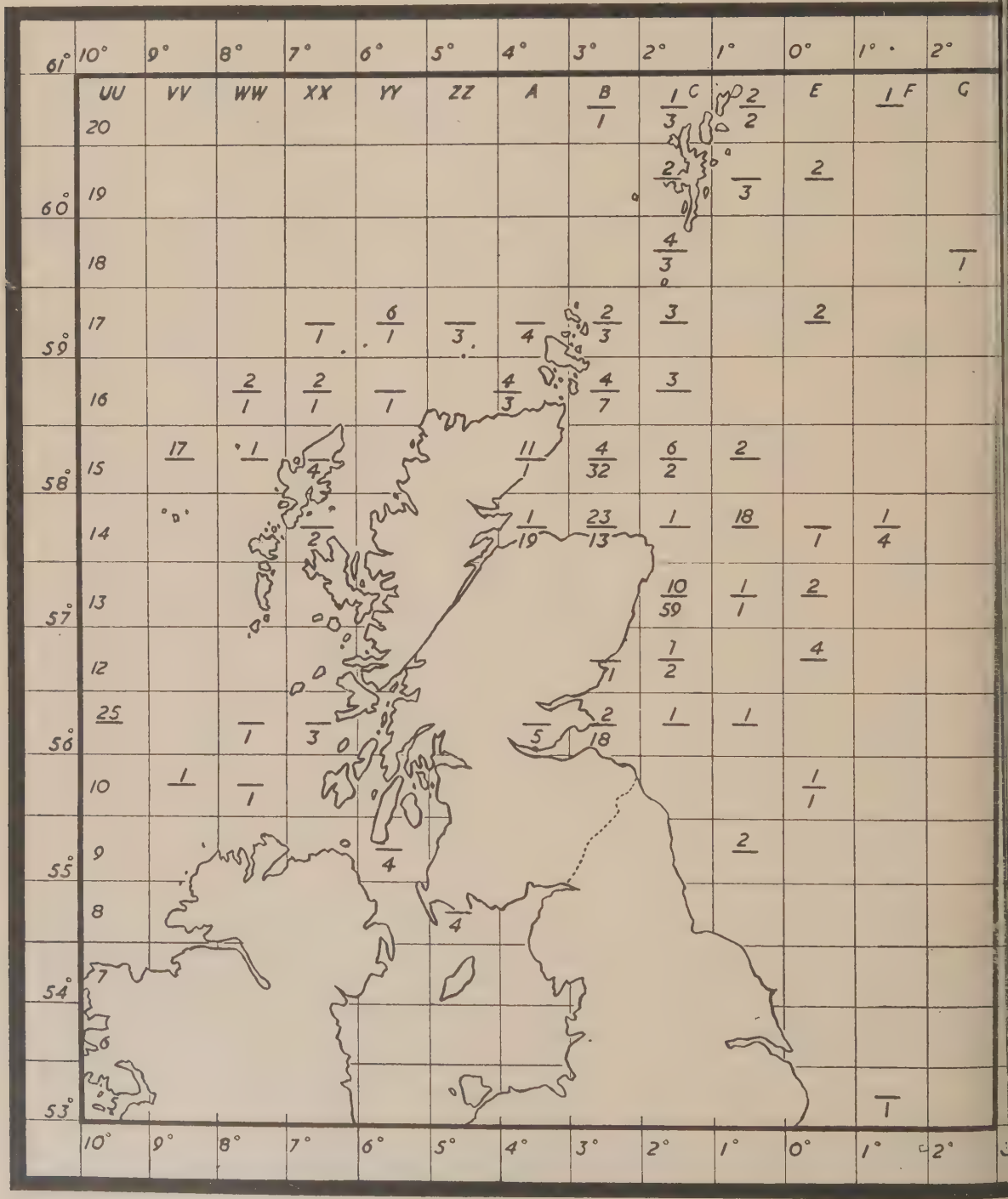

CHART 9.—*Distribution of Oldest Stages of Lemon Sole Larvæ and of Youngest Bottom Life*

Upper figures denote numbers of such larvae in Plankton, collection for period 1929 to 1931. The (lower figures are the ca of baby fish (O and I age groups) made by research vessel trawls from 1922 to 1951.

ng may occur as late as the end of October or even the beginning of November, the age of the larva tion may not have been more than about 4 months. Instances of larvæ passing the first winter in agic state must, however, be regarded as exceptional. The presence of larvæ belonging to stage surface is rather surprising and difficult to explain, particularly since the majority of those caught surface net belong to the upper half of the size range (see Table 8).

ie youngest bottom forms, represented by the six specimens of the O group, were all trawled in ars—three in 1922 and three in 1951. In the former year two were taken in February ghead Bay at a depth of 33 metres and the third in March, near Collieston on the Aberdeenshire t a depth of 25 metres. Their measurements were 43, 48 and 55 millimetres respectively. In vo were caught on Smith Bank (Moray Firth) in February at a depth of 36 metres and the third, February, in statistical area G18d at a depth of 124 metres. These were 50, 60 and 42 millimetres h. Scales were developed on all six specimens. In addition to these Scottish records Holt (1893) es the capture of a lemon sole of 30 millimetres in the trawl at a depth of 145 metres off the Irish Although the age of this specimen has not been recorded it is almost certain to have belonged) Group. It is of particular interest in that it narrows the gap between the smallest bottom forms largest pelagic forms but it should be borne in mind that these O Group fish taken in the trawl bably among the largest and fastest growing individuals of their brood and that smaller fish tedly are to be found on the sea bottom. This view is consistent with the opinion expressed about s at which the larvæ abandon their pelagic existence.

e distribution of the stage 6 larvæ has been plotted on chart 9 on which the occurrence of the bottom stages, less than 2 years of age, has also been shown. An analysis of the depth of the sea over which the larvæ were found shows that 89 were taken in water ranging from 51-100 metres o in water of 100-150 metres, 43 in water of over 150 metres (mostly from two exceptional hauls West coast) and only three in shallow water of less than 50 metres. The fact that most of the stage 6 ere taken in the water layers immediately above the sea bottom, in many cases at a considerable from the shore, seems to indicate that they were preparing to assume the demersal way of life. e depths at which the young bottom forms were caught ranged from 13 to 150 metres. Although higher proportion of the latter were from coastal areas this is certainly due to the more frequent ns of the research vessels in these areas; at the same time comparatively few were taken within e miles territorial limit.

e evidence of the distribution of the oldest larvæ in depth and in space and of the occurrence oung bottom fish is, therefore, strongly in support of the view that the lemon sole larvæ take to he sea bed over a wide area in Scottish waters, representing a wide depth range. Furthermore ribution of the oldest larvæ and youngest demersal forms (chart 9) closely resembles the distribution dolescent and adult lemon soles (Rae 1939 a and c).

ien one considers the thousands of O group plaice and common dabs which are caught annually ourse of research investigations with small mesh netting, it is surprising that so few lemon soles ategory have been recorded but from the discussion in the last few paragraphs it is clear that factors contribute to this scarcity. Foremost amongst these factors is, perhaps, the distribution oung lemon soles at depths greater than those at which the young of the plaice, for example, are and the consequent difficulty of operating suitable catching gear successfully at such depths. all size at which the fish adopt the demersal habit, the smooth elliptical shape and the slow growth y also appear to contribute towards this scarcity. Finally, the habit of the lemon sole of frequenting ttoms of rough gravel, boulders or rocks, which no doubt provide protection against the action rawl and other instruments employed in fishing, would also increase the difficulty experienced apture of the smallest fish.

SUMMARY

This paper is based chiefly on the records of lemon sole larvæ in the plankton catches from the Sea and West of Scotland grounds during the years 1929 to 1931. The larvæ were measured and cla according to their stage of development. The occurrence of the larvæ both in time and place is disc

The spawning period deduced is compared with evidence from other sources and is shown to from the end of March or beginning of April, on west coast grounds, to the end of October or beg of November in the western half of the Central North Sea. Spawning spreads from the west grounds north-eastwards to the Orkneys and Shetlands and then into the Moray Firth, whence it r extends southwards along the Scottish east coast.

The main spawning area in Scottish waters lies in the outer Moray Firth and eastwards t longtitude, and eastwards from the Aberdeenshire coast to the Greenwich Meridian. Spawni least in certain years, is also heavy in a narrow strip from the Butt of Lewis to the Shetlands.

The dispersal of the eggs and larvæ by the prevailing currents is discussed and the importa the effect of the various eddies is emphasised.

The larvæ are shown to be chiefly concentrated in water layers at a depth of 51 to 100 metr to exhibit limited but distinct vertical movements upwards with the onset of darkness and dow with the approach of daylight.

An attempt to correlate numbers of larvæ with numbers of adult fish in later years proved inconc in some localities the numbers of larvæ in the different broods bear some relation to the numb adults but in others the numbers of larvæ appear in inverse ratio to the numbers of adults. It is con that a good spawning does not necessarily result in a good brood survival and that moderate num larvæ may on the other hand, under favourable conditions, produce good recruitment to the stock

Variations in the average size of larvæ throughout the year are demonstrated; as the year adv complete metamorphosis appears to be achieved at a smaller size than early in the season.

The distribution of the oldest larvæ is considered in relation to the occurrence of the youngest b stages. Young lemon soles change over from the pelagic to the demersal way of life on grounds inh by adolescent and adult stocks.

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